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**Global Air Mobility Advanced Technologies
(GAMAT) Advanced Technology
Development (ATD) Phase II
Research and Development**

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

//SIGNED//

MARIS M. VIKMANIS
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Preface

Purpose of this Document

This document is the final report documenting the AFRL / HEC effort entitled *Global Air Mobility Advanced Technologies (GAMAT)* in its 'Phase II' period. The Phase II effort was undertaken as an extension and expansion of the GAMAT Phase I effort.

This final report provides descriptions of the phase II efforts:

- Work-Centered Knowledge Acquisition and Analysis Approach
- Work-Centered Analysis and Design Concepts to Support Air Mobility Command (AMC) 's Tanker Airlift Control Center (TACC) Flight Planning-related Collaboration Work
- Work-Centered Analysis and Design Concepts to Support TACC Flight Planning Work
- Work-Centered Support System for Global Weather Management Spiral 2 Demonstration Capability Research and Development

Related Documents

- *WCSS-GWM Operations Manual (For Scott Air Force Base)*, 12 December 2003.
- *WCSS-GWM Users' Manual*, 17 December 2003.
- AFRL (2003, December). The Foreign Clearance Guide (FCG) Project: *Diplomatic Clearance Solutions for the Integrated Flight Management System - An AFRL IFM / ATD Component*. PowerPoint slide used as SAB poster, December 2003.
- BBN Technologies (2003, July). *Using the ACT Tool - Users Guide*. Application manual produced by BBN in relation to DIP software development.
- Eggleston, R. G. (2003) "Work-Centered Design: A Cognitive Engineering Approach to System Design". *Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting*. Santa Monica, CA. Human Factors and Ergonomics Society.
- Scott, R., Roth, E. M., Deutsch, S. E., Malchiodi, E., Kazmierczak, T., Eggleston, R. and Kuper, S. R., Whitaker, R. (in press) "Work-Centered Support Systems: A Human-Centered Approach to Intelligent System Design". *IEEE Intelligent Systems*.

- SRA International (2002, March). *Advanced Computer Flight Plan Operational Requirements Document*. Report prepared for GSA and AMC under FEDSIM Project Number 97084AFE-04, 29 March 2002.
- *White Paper on the Flight Planning System Assessment*, anonymous review of Advanced Computer Flight Planner (ACFP) and recommendations for the next-generation ACFP and related capabilities, AMC, March 2001.

Project Background

This demonstration capability was developed under the Air Force Research Laboratory Human Effectiveness Directorate's Global Air Mobility Advanced Technologies (GAMAT) Advanced Technology Development (ATD) research and development program. The goal of the GAMAT ATD was to further the development of a new type of user interface technology called Work-Centered Support System (WCSS) technology. The U.S. Air Force's Air Mobility Command's command and control environment was used as the domain for development, testing and refinement of WCSS theories and technology applications.

WCSS Technology

Work-Centered Support System (WCSS) technology is a new cognitive-science-based analysis and design methodology for developing human-computer interfaces and client applications that enable very high user productivity, especially in dynamic and information dense environments. The WCSS technology is applicable to any domain and leverages cognitive analyses and advanced user interface design techniques to provide 'intuitive' user interfaces and client applications customized based on the work requirements. The analysis and design approach is designed to support rapid user adaptation to both routine and non-routine/unexpected events. This is accomplished by providing relevant context and intuitive, directly manipulatable affordances for action. Both form-based and automation-based aiding is used to provide the needed information to support rapid and adaptive problem solving (in the WCSS-GWM, intelligent agents are used as automation aids) and reduce the potential for 'information overload' and associated errors and decreases in work efficiency. The scope of work activities analyzed and potential aiding concepts includes support for decision making, product production, collaboration and coordination, as well as individual and team level work organization.

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1.1 Knowledge Acquisition and Analysis Approach

A fundamental aspect of the work-centered design approach is an analysis and modeling of the *work ecology* to uncover the *elements* of work that require support. The process starts with knowledge acquisition (KA) methods such as ethnographic field observations and structured interview techniques to uncover the characteristics of the work domain, the work requirements, the sources of complexity and cognitive and collaborative demands entailed. Formal methods can then be employed to represent the results of the analysis (work ecology modeling). These include work domain analysis methods that model the intrinsic characteristics of the work to be achieved as well as methods that model workflow dynamics within and across individuals and groups required to achieve work goals.

The products of work ecology modeling define the work-aiding requirements to support domain practitioners in performing work in a flexible and adaptable manner, given the dynamics of the work context. These requirements are used to guide work-aid design that involves development and prototyping of work-aiding concepts. Work aiding may take the form of *representational aiding* that is provided through the use of work domain visualizations or *direct aiding* provided by a coordinated set of software agents that interact with the user that are clearly connected to or are embedded in the work domain visualizations (Eggleston, 2003; Scott, et al., in press).

The knowledge acquisition effort in the present project focused on current flight-planning practices at the U.S. Air Force Air Mobility Command (AMC) at Scott Air Force Base, and opportunities to employ work-centered support system concepts to improve it. The location of the operations studies were in AMC's Tanker Airlift Control Center (TACC).

KA Collection

KA collection activities were undertaken with the overall objective of modeling the ecology of the work environment that is currently in use for flight planning. Activities consisted of interviews and observations whose specific objectives were to:

- Understand the 'as-is' process
- Understand sources of task complexity:
 - In both routine cases as well as non-routine situations that are important to support
 - Examine inherent constraints in the domain that complicate performance
- Understand cognitive and collaborative processes that need to be supported (within and across organizational boundaries)
- Define work-centered design approaches and software agent technologies to enable more proactive response

Focus of observations and interviews included:

- The current Flight Planning process employed by the flight planning shop
- The interaction between the flight planning process and the DIP Clearance process
- How the flight planning process fits into the larger mission-planning process
- The work and perspectives of other important contributors to the flight planning process:
 - Flight Managers
 - Execution Cell operations (Formerly East and West Cell)
 - XOCX aerial ports cell

A second aim of the knowledge acquisition effort was to obtain feedback on preliminary WCSS design concepts that were developed as part of this program. Story boards illustrating proposed WCSS design concepts were presented to representatives of the target user communities to elicit their feedback as an aid to prioritizing the design ideas and further refining them.

Collection Methodology

Analysts undertook five, multi-day, KA-survey trips to AMC, the first in December of 2002, with additional visits in the following March, June, September, and November of 2003.

During the KA trips analysts undertook interviews with the following groups involved in flight planning work:

- Flight Planning Shop
- “Customers” of Flight Planning product:
 - DIP Shop
 - Mission Planners
 - Flight Managers
 - Execution Cell
- AMC staff involved in shaping future of the TACC

KA Analysis

KA analysis consisted of an effort to diagram the flight-planning process, to understand the dynamics of the process, and sources of task complexity with a view toward developing Work-centered Support System (WCSS) concepts for improving performance. The analysis effort generated a variety of aids to facilitate understanding current practices, including aids to:

- Visualize the current overall flight planning process
- Visualize the TACC staff roles involved and the way they interact.
- Identify sources of actionable issues (e.g., complexities, delays)

Figure 1 shows an example of one of the aids generated. Others are provided in Appendix B.

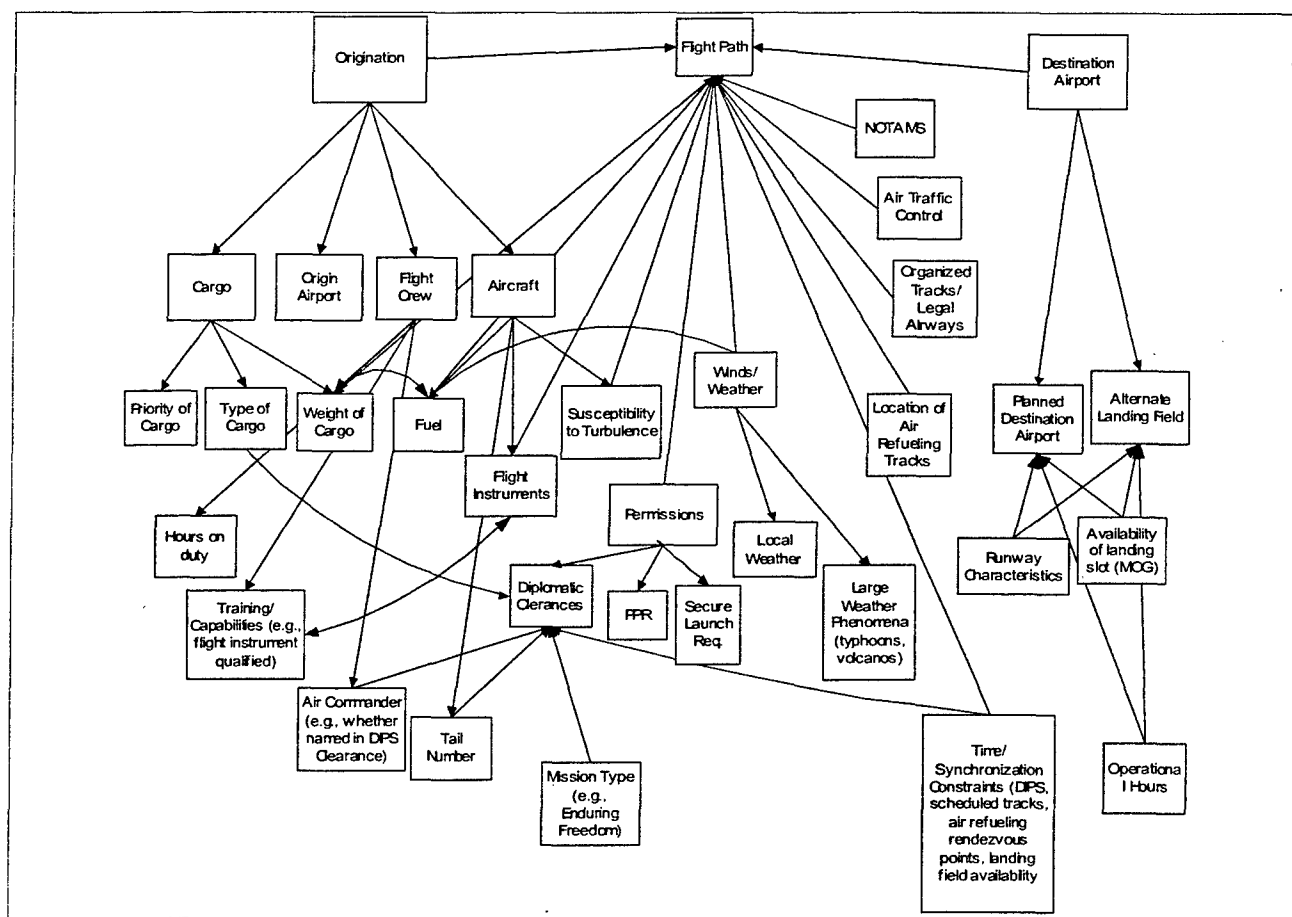


Figure 1: Mapping among Interacting Factors Affecting Flight Planning

Design Recommendations and User Feedback Session

After iterative KA sessions and analysis, basic findings and preliminary recommendations were presented to multiple AMC personnel and feedback was solicited relative to those findings and recommendations during a session on 12 Nov 03. This was in addition to the initial individual KA sessions and informal follow-up. During the 12 Nov 03 session, feedback was solicited regarding:

- The usefulness of the proposed capabilities:
 - Would you use it?
 - In what situations?
 - What other groups (positions) might find this useful?
- Potential additional enhancements that would be useful that should be analyzed further

1.2 TACC Flight Planning-related Collaborative Work and Flight Planning Work Analysis and Design Effort Overview

During the first phase, the Global Air Mobility Advanced Technologies (GAMAT) research and development program investigated the efficacy of applying the emerging Work-Centered Support System (WCSS) methodology and resulting client applications to support a select portion of the Air Mobility Command (AMC) work domain. The effort researched, developed and demonstrated performance-enhancing information technologies (IT) in support of weather (WX) impact mitigation on AMC managed airlift and tanker aircraft missions, called the Work-Centered Support System for Global Weather Management (WCSS-GWM).¹ The results of this work were briefed to AMC customers and documented in a final report. Toward the end of the GAMAT Phase I effort the GAMAT team was directed to begin consideration of applying WCSS principles and designs to the entirety of the AMC / TACC environment.

In Phase II of the GAMAT effort, we continued our Phase I work with regard to two topics as follows:

- The WCSS-GWM tool from Phase I was carried over for limited refinement, test deployment, and evaluation.
- The Phase I assignment to develop WCSS concepts addressing the whole of AMC / TACC collaborative work processes was carried over as a focus for ongoing Phase II consideration.

Beyond these 'carry-over' themes, our Phase II work was directed toward flight planning as a central focus. In previous projects AFRL teams had studied channel mission planning (Human Interaction with Software Agents (HISA) project), integrated flight management (IFM project), and TACC weather operations (GAMAT Phase I). This left the 'flight planning shop' as the largest mission work process chain yet to be examined. In Phase II our knowledge acquisition (KA), analysis, and design efforts were therefore concentrated primarily on the flight planners (FP's).

In addition to these foci for GAMAT Phase II study, some other TACC units and functions were addressed. Owing to the importance of the flight planners' recurrent interactions with mission planners (MP's) and with the diplomatic clearances (DIP's) shop, we accorded secondary attention to those units. In accordance with the emerging importance of the new 'execution cell' or 'execution floor' facility within TACC, we also gave attention to that organizational unit.

The Phase II Effort in Terms of Subject Work(er) Granularity

The specification of an overall WCSS concept within the GAMAT Phase I project context was described with regard to three distinguishable levels of organizational granularity:

¹ At various times, the WCSS-GWM had also been referred to as 'GAMAT', 'GAMAT prototype', and 'Weather Management Tool (WMT)'.

- *Individual User.* This level of granularity pertains to consideration of a single worker or user. In the case of GAMAT Phase I, this was the granularity at which the WCSS-GWM was framed.
- *Group / Cluster of Users:* In the case of GAMAT Phase I, this was the level of granularity at which we addressed (a) the 15th OWS weather 'shop' as a unit, as well as the 'swimming pool' group consisting of the 'front office' WX officer and the flight managers (FM's).
- *Organization:* This level of granularity encompasses the entirety of TACC as a mission planning / supervising entity. In GAMAT Phase I this level of granularity was addressed only in the context of the late-stage assignment to examine the whole of TACC mission operations.

The Phase II GAMAT effort can be characterized in similar terms as follows:

- *Individual User.* In the case of GAMAT Phase II, this was the granularity at which we framed the flight planning analysis / designs, the WCSS-GWM evaluations, our examination of DIP shop operations, and our limited examination of mission planning functions.
- *Group / Cluster of Users:* In the case of GAMAT Phase II, it was this level of granularity at which we considered the MP / FP / DIP functional 'cluster' and the interactions among the positions in the execution cell.
- *Organization:* In GAMAT Phase II this level of granularity was addressed as the context for information technology (IT) innovations and interventions affecting multiple TACC units as well as the grounds for revising the number and type of specific interface concepts comprising our proposed suite of WCSS.

The Phase II Effort in Terms of TACC Mission Process Paths

Beginning in 2000, AMC/ TACC undertook a major initiative to redesign their organization and work practices to better meet the demands of modern air transport operations. One aspect of this initiative was to formulate and implement the concept of *integrated flight management (IFM)* and the role of the *flight managers (FM's)*. The FM concept was based on dispatchers in commercial airline operations. At this point in time, the IFM concept is only partially implemented within TACC. Although the proportion of 'flight-managed' missions has grown substantially in the 3 years since the first cadre of 6 FM's began working in 2000, it still accounts for a minority of all TACC missions.

The point of relevance is that for the time being and for the foreseeable future, TACC will be processing missions and flights through two distinct work process paths. The first is the current version of the 'traditional' path, leading from mission planning through flight planning to execution and flight monitoring. The second is the IFM path, leading from mission planning through the FM staff to execution and flight monitoring. Both paths originate with the mission planning shops. They converge again in the execution cell. The details of each path's middle portion describe the main divergence between them.

Our earlier projects had focused on one or the other process path (for those efforts in which our subjects were dedicated to only one). The HISA project's focus on channel mission planning predated the implementation of the IFM concept, and hence concentrated on the 'traditional' process path. The IFM project, on the other hand, concentrated on the new way of doing things. To the extent it related to one versus the other, the GAMAT Phase I effort focused more on the IFM path than the traditional one (e.g., in analyzing the work of the 'front office' WX officer working with the FM's in the 'swimming pool'). However, because the WX shop supports both the traditional and the IFM branches of the TACC workflow, the results of GAMAT Phase I are essentially neutral with respect to the interpath distinction.

The new design aspects of the GAMAT Phase II effort focused upon flight planning and upon overall TACC collaboration. In subsequent chapters of this report, we shall examine each of these aspects in turn. Chapter 1.3 will discuss our work with respect to overall TACC collaboration. Chapter 1.4 will discuss the generation of new WCSS design concepts specifically tailored to flight planning and related TACC functions. Chapters 1.5 and 1.6 will introduce and discuss WCSS design innovations generated in response to these topics.

1.3 Analysis of TACC Flight Planning-related Collaborative Work

This chapter will address our GAMAT Phase II work insofar as it relates to collaboration among TACC units and for TACC as a whole. Given our customer-specified focus on flight planning operations, our consideration of collaboration issues concentrated on the interactions and interdependencies among flight planners (FP's) and others within the TACC.

Beginning in 1999, AFRL has conducted a series of projects focused on TACC mission processes and tasks (HISA, IFM, GAMAT Phase I, GAMAT Phase II). Each of the pre-Phase II projects were directed toward one or another particular function or position within the many comprising TACC (mission planners in HISA; FM's in IFM; WX staff in GAMAT Phase I). With GAMAT Phase II we more or less 'filled in the final gaps' in our perusal of the core TACC mission process path by examining the flight planners, the DIP planners, and the recently-implemented Execution Cell. This is not to say that we have a complete understanding of the complexities of TACC and its operations. However, it is fair to say that with Phase II we have assembled an overview of the mainline operations. This means that it was not until Phase II that we could reasonably evaluate the current and potential nature of collaborative work in TACC.

TACC's Organizational Structure and the Prospects for Collaboration

'Collaboration' is one of those terms which can be trivialized into a generic 'good thing'. In colloquial usage, it carries the connotation of 'multiple people working together on a common work product'. In some sense, and at some level of granularity, all organizations can be construed as relying upon 'collaboration' in this sense. The prospects for fostering more or better collaboration within an organization are not uniform or universal. For one thing, some work processes are more amenable to collective or group cooperative tasking than others. Moreover, some organizations may have sound reasons (e.g., security; resource issues) which lead them to enforce relatively compartmentalized approaches to work processes of joint production by multiple players.

The fact remains that there are some activities where subsidiary tasks are sufficiently well-defined as to be most efficiently accomplished by specialized individuals (or sets of individuals), operating in relative isolation from peers or parallel persons, contributing to the same overall process or product. Even in such cases as these, there may still be grounds for promoting 'collaboration', but in a sense other than 'multiple people working on a common work product'. This variant occurs when the otherwise-compartmentalized functions, no matter how efficiently conducted in and of themselves, must contend with conditions and constraints relating to other peer functions (and / or external conditions mediated by peer functions). In such cases, the point is to ensure that each of the compartmentalized subunits do not separately and efficiently contribute to a work product which is 'wrong' (i.e., ineffective) when evaluated as a composite output. The usual label for keeping individually-*functioning* peer elements jointly-*informed* on what and how to accomplish the team's work is 'coordination'.

TACC is a large organization subdivided into several functional subunits. These subunits are delineated with respect to particular roles within or aspects of the progression from initial mission plan through to mission execution. This organizational architecture therefore compartmentalizes the participating staff within specialized subcomponents of the overall TACC team. This leads to a corresponding compartmentalization of functions and responsibilities along the timeline leading from mission planning through to execution. In effect, TACC is currently configured in a manner which does not promote multiple staffers working together on a common work product in realtime or even in near-realtime. The implication is that TACC (as currently configured) functions on the basis of common effort, but not through any comprehensive 'collaboration' in the sense typically attributed that term. To be sure, there are particularly junctures in the TACC process path where individuals within functional subunits (e.g., the flight planning shop; the former 'swimming pool' for the FM's) confer or cooperate. However, even at these finer-grained levels of granularity there are few persistent examples of multi-person 'collaboration' to be found.²

By the same token, all these relatively compartmentalized individuals and subunits must make decisions whose correctness is predicated on what others are doing, have done, or will do. Furthermore, each of these individuals must be prepared to modify mission plans in response to changes resulting from the actions of their peers (and, of course, external parties for which peers are the primary points of contact). The single most common resolvable breakdown condition cited over the years we've been studying TACC is that which occurs when one or another aspect of a mission's plan is invalidated without the person(s) responsible for necessary corrections knowing it. In other words, the solution path for optimizing TACC team operations is more along the lines of facilitating 'coordination' among individually-specialized elements than instituting literal 'collaboration' among them.

As a result, our Phase II GAMAT collaboration work has not focused on design concepts specifically tailored to multiple people 'collaborating' in realtime. Instead, we have concentrated on design concepts which permit multiple players (perhaps in widely-separated locations) to jointly view and / or manipulate relevant mission information. In other words, we have sought to support overall team work processing without configuring our designs such that team members must link up synchronously to exploit these design concepts. Conversely, the design concepts have been developed so as to avoid preventing or ruling out realtime 'collaboration' among team members. The point is that we have deliberately avoided *forcing* realtime collaboration among TACC team members in our design work.

The Role of Flight Planning in TACC Collaborative Work

TACC functions as the central planning and supervisory nexus for USAF airlift operations. Internally, the TACC is subdivided into multiple subunits, each with its own specialized function. All these subunits, however, contribute to an overall work flow which leads from initial mission planning through to monitoring of missions in flight. At the 'upstream' end of this work flow, planning concentrates on incoming requirements for movement of materiel and generates basic specifications for discrete actions to effectuate these movements. Loosely speaking, this can be seen as dealing with the 'theory' of a

² The primary exception to this claim is to be found in the Execution Cell (i.e., on the 'Ops Floor'), where a confederation of specialists work jointly to oversee missions in flight. Even in this case, however, the idea of a persistent sub-team working on a particular mission is neither the rule nor a practical prospect.

mission. At the 'downstream' end the actual flights by which the movements are effectuated are overseen. Loosely speaking, this can be seen as dealing with the actual 'practice' of executing a mission.

The flight planning function lies in the middle of this work flow progression. This middle position in the sequence of case (mission) processing is reflected in flight planning's centrality to the entire operation. More specifically, flight planning represents the point within the plan-to-execution progression at which:

- a mission's 'theory' becomes converted into a concrete specification for transport 'practice'
- the planning context shifts from abstractions or categories (e.g., aircraft type) to concrete specifics
- functional constraints extrinsic to AMC (and even USAF) must be considered and dealt with
- legal and regulatory constraints (e.g., ATC rules) extrinsic to AMC (and even USAF) must be considered and dealt with
- resource constraints (e.g., fueling) must be assessed and planned for
- temporal issues (e.g., scheduling details) must be evaluated and accounted for
- short-term dynamic constraints (e.g., weather) can first be encountered
- planners must operate within a problem space where the constraints and rules might be shifting at any time
- TACC personnel actively undertake a task which the aircrew must accomplish before taking off
- the sort of details or specifics with which the execution cell and aircrews must grapple are first locked in
- primary IT support shifts from CAMPS to GDSS

In other words, although all phases of the plan-to-execution progression are important, flight planning stands out as the best nominee for 'most critical juncture' in the entire process. One can conceive of an aircrew taking off on a 'null transport mission' (i.e., one accomplishing no 'transport mission objective'), but still requiring a flight plan to do so. Conversely, one cannot conceive of executing a transport mission objective without having a flight plan detailing how it's to be accomplished.

Temporal Issues in TACC Collaboration

During the course of our GAMAT Phase II work, we repeatedly encountered references to key timeframes and time points affecting the overall planning process and the operations of the execution cell. These temporal features generally related to time constraints and practical guidelines for avoiding their impacts. In the planning phase, the most critical time constraints noted related to the DIP clearance process.

The tables below summarize some of the timeframe and time point parameters cited by subject matter experts (SME's) during the course of our Phase II work, as well as some similar temporal features collected in our earlier AMC projects. The tables are differentiated on the basis of the way the timeframes are delineated by the TACC staffers who observe them. Some actions are triggered on a 'demand basis', and hence are subject to consideration in terms of an incidental timeframe. Some actions are performed on a recurrent basis with regard to a particular periodicity (e.g., every X hours). Some are performed with respect to a look-ahead period into the future. Finally, some are performed with respect to a given length of time prior to an expected future event (most commonly a mission's / sortie's take off). All of these categories involve organizing work with respect to temporal features, but each is distinct from the others in the way in which it is defined with respect to a timeline.

The point in enumerating these categories and the various activities correlated with each of them is to illustrate the diversity of temporal references 'in play' among TACC operations. For some tasks, a given staffer is orienting with respect to a fixed time point on the clock, whereas for others he / she may be orienting to a more fluid expanse of time. For many (most particularly the 'incidental' ones), he / she is incapable of organizing the work and must address the given issue or task as it pops up. The diversity of observed timeframes, plus the proportion of tasks inimical to temporal organization, illustrates the potential for conflicting temporal priorities among TACC workers.

The first category, illustrated in Table 1.3-1, subsumes those activities which are conducted on an 'on-demand' or 'as able' basis. Relative to the other categories and tables, this one is clearly the largest. This implies that 'incidental' tasks are the largest category of tasks (as delimited with respect to timeframes). This in turn implies that TACC's overall work processes are subject to variations in terms of loads, priorities, and attendant stressors depending on circumstances. All this validates the informal impression that TACC activities are to a large extent 'reactive' - both in terms of reacting to pop-up requirements and in terms of reacting as one is able.

Table 1.3-1 Examples of Incidental Timeframes in TACC Work

TIMEFRAME	ROLE	ACTION / EVENT
As able	Mission Planner	Begin mission planning actions on a newly-posted mission.
As needed	Mission Planner	Issue request for DIP clearances on a given mission being planned
As needed	Mission Planner	Issue request for notional flight plan to the flight planning shop
As needed, no later than T-24 Hours	Mission Planner	Issue request for PPR clearances on a given mission being planned
As able	Flight Planner	Accrete ('publish') mission plan to GDSS
As able	Flight Planner	Process Mission Planner request for a notional flight plan
As able	Flight Planner	Begin flight planning actions on a mission / sortie in the pending queue
As needed	Flight Planner	Issue request for DIP clearances on a given mission being planned
As able	Flight Planner	Accrete fully developed flight plan to TACC info systems and resources
As able	DIP Shop (MP requests)	Process Mission Planner request for DIP clearances
On Demand	DIP Shop (cell changes)	Process DIP clearance requests deriving from cell changes
As able	DIP Shop (position handling follow-ups)	Follow up on DIP clearance requests still awaiting response from foreign granting authority.
As happens	ACFP 'F2' Database Maintainer	Receive info on DAFIF-relevant changes from contacts (e.g., FM's, ATC authorities) ¹
As needed	ACFP 'F2' Database Maintainer	Contact NIMA to request updates to DAFIF info to reflect changes he's uncovered from other sources. ²
As needed	ACFP 'F2' Database Maintainer	Review nominated route specifications for inclusion into the F2 database
As needed	ACFP 'F2' Database Maintainer	Accrete nominated route specifications into the F2 database.
As able	ACFP 'F2' Database Maintainer	Review and evaluate stored F2 route specifications for modification(s) and / or retention.
3-4 times daily	ACFP 'F2' Database Maintainer	Typical frequency of updates to F2 DB ³
8 times daily	ACFP 'F2' Database Maintainer	Maximum estimated frequency of updates to F2 DB ⁴
As able	Flight Manager	Issue flight plan specification to relevant ATC authority(-ies) for approval
As needed	Flight Manager	Revise flight plan in response to negative feedback from ATC
As able	Flight Manager	'Paper the crew'
As needed	Execution cell	Take action to attempt to correct mission problems identified during the pre-launch 'scrub'.
On Demand	Execution cell	React to pop-up issues with missions being executed.
On Demand	Execution cell	Undertake re-planning on missions that cannot be completed in

¹ Source: Roth (2003, October)

² Source: Roth (2003, October)

³ Source: Roth (2003, October)

⁴ Source: Roth (2003, October)

The second category, illustrated in Table 1.3-2, subsumes those activities which are conducted on recurrent basis that is delineated with respect to a discrete period of time. Relative to the other categories and tables, this one is clearly the smallest. This implies that 'cyclical' tasks are the category least likely to be prescribed in a work domain as fluid as mission planning and monitoring. This in turn implies that TACC's overall ability to control loads, priorities, and attendant stressors through specification of cyclical or recurrent standardized tasking is very limited.

Table 1.3-2: Examples of Recurrent Timeframes in TACC Work

TIMEFRAME	ROLE	ACTION / EVENT
<i>Recurrent / Cyclical Timeframes:</i> These subsume those requirements and activities done on a continuous / cyclical basis, delineated with respect to a given time span or periodicity.		
Every 28 days	F2 Database Manager	Nominal / official cycle time for updating DAFIF data. ¹
Every 28 days	F2 Database Manager	Nominal / official cycle time for refreshing F2 DB. ²
Every 28 days	F2 Database Manager	Nominal cycle time for updating 'canned flight plans' posted to bulletin board. ³
Every 12 hours	Flight Planners / FM's	Cycle time for assignment of current North Atlantic Tracks (NAT's). ⁴
Beginning of each shift	Flight Planners	Do 'sort' of allocated missions listing for work assignments within FP shop. ⁵
Beginning of each shift	Flight Planners	Selection of appropriate NAT for the day's flight planning of transatlantic missions. ⁶
Beginning of each shift	Flight Managers	WX briefing
Every 6 hours	WX - Chartmaker	Update all charts for areas in which IFM missions are scheduled to operate.
Every 6 hours	WX - Chartmaker	Update all charts for areas in which IFM missions are scheduled to operate.
Hourly	WX - Chartmaker	'Trip around the world' - General metwatch review and assessment

¹ Source: KA visit to XOCZ, December 2002; Roth (2003, March).

² Source: KA visit to XOCZ, December 2002.

³ Source: Roth (2003, March).

⁴ Source: KA visit to XOCZ, December 2002.

⁵ Source: KA visit to XOCZ, December 2002.

⁶ Source: Roth (2003, March). The SME stated this selection is done 'at the start of each day'. Given the 12-hour cycle time for updating NAT specifications, it is assumed he was referring to the start of 'one's work day' (i.e., a shift) rather than a 24-hour period.

The third category, illustrated in Table 1.3-3, subsumes those activities which are conducted in accordance with a time point delineated with respect to a discrete period of time extending into the future. To date, the 'chartmakers' in the weather back shop are the primary category of TACC staffers whose work is clearly delineated in this fashion. This is not really surprising, given that the WX chartmakers are generating generic (non-mission-specific) information products (WX charts) for their audience(s). Their time constraints therefore relate to an external and relatively unchangeable phenomenon (the weather) rather than something subject to modification by TACC itself.

Table 1.3-3: Examples of 'Look-Ahead' Timeframes in TACC Work

TIMEFRAME	ROLE	ACTION / EVENT
Prospective / 'Look-Ahead' Timeframes: These subsume those requirements and tasks associated with a given 'look-ahead' temporal horizon delineated as a time span extending forward from the present.		
48 hours' look-ahead	Ops Floor / 'MOG Meister'	Maximum look-ahead afforded by current MOG tool ¹
10 hours' look-ahead	Flight Planner	Nominal look-ahead horizon for printing out list of allocated missions to be worked by FP's ²
9 to 10 hours' look-ahead	WX - Chartmaker	Chartmaker's stated look-ahead time for generating most immediate (6-hour look ahead) WX charts.
0 to 6 hours' look-ahead	WX - Chartmaker	Hazard charts for areas in which IFM missions will operate.
6 to 12 hours' look-ahead	WX - Chartmaker	Hazard charts for areas in which IFM missions will operate.
12 to 18 hours' look-ahead	WX - Chartmaker	Hazard charts for areas in which IFM missions will operate.
18 - 24 hours' look-ahead	WX - Chartmaker	Hazard charts for areas in which IFM missions will operate.

¹ Source: Roth (2003, October)

² Source: KA visit to XOCZ, December 2002.

Granted, there are other classes of workers (most particularly in the Execution Cell) who would like to be able to conduct their work with respect to such a regularized 'look-ahead' horizon. However, those other roles currently have to try and achieve 'look-ahead' with respect to a deadline preceding a critical event (most commonly mission / sortie launch). This type of look-ahead temporal framing is addressed in Table 1.3-4.

Table 1.3-4: Examples of Fixed-Point Prospective Timeframes in TACC Work

TIMEFRAME	ROLE	ACTION / EVENT
<i>Prospective / 'T-X' Timeframes:</i>		
These subsume those requirements and tasks associated with a given 'look-ahead' temporal horizon delineated with respect to a particular time point - mission / sortie launch.		
T-2 or 3 months	Mission Planner (Channel)	Maximum lead time for planning missions
T-2 or 3 months	Mission Planner (Channel)	Maximum lead time for MP requesting DIP's
T-2 Weeks	DIP Shop	Maximum lead time cited in XOCZ KA, December 2002
T-24+ Hours	DIP Shop - position handling MP requests	Process DIP requests from Mission Planners (generally presumed to be 24 hours or more in advance of mission / sortie launch).
T-24 Hours <i>minimum</i>	Mission Planner	Request PPR (Prior Permission Required) clearances
T-24 Hours	Mission Area Representative (MAR)	MAR 'adoption' of mission under his / her control / oversight.
T-24 Hours	Mission Planner	Nominal timeframe for Mission Planner 'handing off' control of pending mission to execution cell or FM's. ¹
T-24 Hours	Ops Floor personnel	Ops floor 'adoption' of mission for control / oversight thereafter. ²
T-24 Hours <i>maximum</i>	DIP Shop - position handling 'cell changes'	Process DIP requests motivated by 'cell changes' (plan modifications induced within 24 hours of launch).
T-24 Hours <i>maximum</i>	DIP Shop - position handling 'pending requests'	Follow up on outstanding DIP requests relating to missions / sorties scheduled to launch within 24 hours.
T-10 to T-12 Hours <i>minimum</i>	Flight Planners	Typical minimum lead time for FP planning actions ³
T-10 to T-12 Hours	Flight Planners	Typical timeframe for finalizing FP and handing it off (never to be reviewed again by FP, barring exceptions) ⁴
T-10 to T-12 Hours	Flight Planners, Execution Cell, FM's, Aircrews	Beginning of 'blind spot' period between FP finalization and mission launch.
T-6 Hours	Flight Planner	Absolute deadline for completing and exporting flight plans ⁵
T-6 Hours	Execution Cell - General	Conducting a precautionary 'scrub' (review) of missions lined up for imminent execution.
T-6 Hours	APCC	Give final confirmation whether Hazmat is involved on a given mission.
T-6 Hours	APCC	Give final confirmation of estimated aircraft gross weight on a given mission.
T-4 to T-6 Hours	Flight Manager	Begin construction of crew papers package.

¹ Source: Roth (2003, March; 2003, October)

² Source: Roth (2003, March; 2003, October)

³ Source: KA visit to XOCZ, December 2002.

⁴ Source: KA visit to XOCZ, December 2002.

⁵ Source: KA visit to XOCZ, December 2002.

Issues Deriving from Operational Timeframes Currently Observed

The timeframe features enumerated in the tables above serve to illustrate some of the issues which cause collaboration and coordination problems for TACC personnel. In the subsections below we shall illustrate this with some selected examples which are clear enough to have motivated comments from SME's during our Phase II knowledge acquisition (KA) work. Some of these examples relate to differences in the timeframes within which different roles and units operate. Others involve access to information not ordinarily available within a given role's timeframe during which that information would be useful.

Two Flight Planning Horizons with which the Flight Planners must Contend

One of the things we discovered in our flight planning KA is that flight planners must deal with not one but two general types of flight planning. The first, and earlier, one is the generation of 'notional' flight plans for the benefit of the mission planners. This is done to provide the mission planners with what might be termed 'initial sketches' of prospective routes so that they can evaluate options, constraints, and possibilities. The most time-critical aspect of notional flight planning is that it provides the mission planners with the ability to specify those nations for which DIP clearances must be obtained. Because the DIP shop needs to be processing DIP requests 1 or more days ahead of mission launch, this work must be initiated prior to the flight planners' nominal timeframe for final detailed flight planning (which can run as little as 10 - 12 hours prior to launch).

The second, and subsequent, type of flight planning is of course the final detailed plan creation one typically associates with the flight planning shop. With respect to those missions for which notional flight plans (and DIP's) have already been processed, this latter flight planning phase provides a waypoint at which the flight planner can evaluate those earlier outcomes with the routing and scheduling details he / she is currently specifying. The problem is that the mission planning phase (and the attendant DIP processing) may have been conducted quite some time in advance of this final flight planning activity. This means that there may have been more than enough intervening time to allow all manner of relevant changes to have occurred which complicate or even invalidate the mission plan parameters originally laid out. What's worse is that this final flight planning activity is typically undertaken as mission launch approaches. This puts the flight planner under heightened pressure in the event problems are identified at this relatively late date.

Both the notional and the final flight planning activities involve recourse to ACFP and the production of route specifications. The final version, of course, involves considerably more fine-grained detail and presumably more flight planner time and effort. This implies that to the extent the relatively less-constrained and less-critical notional flight planning activity could be speeded up or shifted off their agenda, the flight planners would be freed up to more effectively deal with their final flight planning.

Late Arrival of Relevant WX Info to Flight Managers

In reviewing our WCSS-GWM prototype in September 2003, flight managers mentioned a disconnect between their work and that of the WX shop. By the time the flight managers get the weather package for a given flight it is too late for the WX info to help them in developing the flight plan (since the weather package typically is attached to the crew papers after the flight plan has been generated or finalized).³ General WX charts are being produced by the WX back shop in time to be available during the FM's typical planning timeframe (circa T-4 to T-6 hours). Unless they proactively seek out current WX chart info, the FM's generally don't see the WX data until the relatively late point cited in these KA comments.⁴

³ Source: Roth (2003, October)

⁴ This is not a new issue. During the initial IFM project KA effort (December 2000), FM's were observed to occasionally walk over to the designated WX workstation in the 'swimming pool' and examine available WX charts while the WX specialist was away. During our KA visits in the FY02 GAMAT Phase I effort we observed considerable conversational chatter between the WX 'front office' staffer and FM's seated nearby.

Vulnerability to Dynamic Changes External to TACC / USAF

A recurring complaint we've encountered dating back to the HISA project in FY99 concerned the way in which shifting circumstances outside the scope of direct inspection (and hence outside the immediate ken) of TACC planners can 'clobber' a mission or flight plan. Such changes can originate with any of the players associated with executing a mission, and they may pop up at any time. The range of such potential changes can be illustrated with the following examples cited during our Phase II KA activities:⁵

- Change requests incoming from the pilot / aircrew
- Changes to cargo parameters (amount; weight, etc.)
- Changes relating to presence of Hazmat (e.g., late recognition that Hazmat is involved; Hazmat being substituted on a priority basis for some originally-intended cargo)
- Changes in DIP clearance viability or the regulatory bases for DIP clearances
- Changes in airfield availability or operating parameters (e.g., via Notice to Airmen (NOTAM's))
- Changes in scheduling pertaining to assets assigned to the planned mission (e.g., aircrew, aircraft, specific cargo items)
- Changes in routing or scheduling relating to significant weather conditions (e.g., tropical storms)
- Changes in scheduling deriving from crew rest requirements
- Changes in aircraft availability deriving from maintenance requirements

In general, such dynamic changes can jeopardize the viability of a flight plan at any time during the planning / execution process. Such changes become particularly problematical as the time for mission launch draws near, because:

- It is only at this relatively late stage in the process that certain key facts and factors can be determined with any certainty.
- It is at this late stage that opportunities for timely adaptations capable of 'saving' a mission plan diminish or disappear.
- The delay until one can access newly-issued or updated information (e.g., new NOTAM's) typically equals or exceeds the planning horizon at this late stage.

⁵ This illustrative listing is drawn from information gathered during GAMAT Phase II KA efforts in December 2002, March 2003, June 2003, and October 2003.

- To the extent it is available at all, definitive information about remote (i.e., on-site) circumstances can sometimes only be obtained through direct contact with a relevant remote authority.
- Particularly during our Phase II timeframe (with multiple overseas theaters having to be supported) the opportunities for corrective replanning had become even more constrained owing to demands on USAF assets (e.g., aircraft, crews).⁶

It is difficult to get a sense of what proportion of execution-ready flight plans typically have to be re-planned as mission launch time approaches. One of the few clues we were able to obtain came from an interview with the International Flight Plans and Diplomatic Clearance Office's (XOCZ) Major Barton. He noted that during a 6-hour shift on a recent day there had been a total of some 70 flight plans to execute, while there were some 19 material changes that had to be processed. Even if this frequency of replanning were double the 'norm', it would insinuate a replanning incidence of at least 13% of pending missions.

To deal with such changes under time pressure, TACC staffers must obtain relevant or current data from authoritative sources. For factors such as those addressed in this subsection, such authoritative sources are external to TACC itself. This means that external contacts are an important tactic in trying to keep up with events and conditions. We have seen such external contacts employed in most of the TACC units we've studied over the last 4 years. In the IFM project (FY01) we observed FM's repeatedly taking the time to call ATC and on-site airfield centers to double-check on conditions, constraints, etc. In the GAMAT Phase I project (FY02) the staffers performing the WX 'chartmaker' role consistently mentioned the occasional need to seek detailed on-site (e.g., airfield) data, even at the cost of a direct contact. For the flight planners, email to and from Euro Control and / or UK ATC is a common channel used to double-check on conditions and changes for the all-important European airspace.⁷ The importance of such external contacts to the DIP planners is evidenced by their habit of maintaining 'contacts folders' containing key contact data.⁸

⁶ Source: Interview with Major Barton of XOCZ (Roth: 2003, March).

⁷ Although both Euro Control and UK authorities issue regularly-updated routing data in the form of the *Route Access Document (RAD)*, there are still cases in which the cycle time for updating the RAD exceeds the timely planning horizon for the flight planner. (Source: KA with XOCZ, December 2002).

⁸ These contact folders include such things as FSG information on DIP requirements for the given country, numbers of blanket clearances available, Hazmat requirements and rules, phone numbers for key DIP authorities, contact number for the U.S. Embassy DAO office in that country, and miscellaneous other remarks as necessary. (Roth: 2003, March)

Timely Availability of APCC-Supplied Data to Flight Planners / Flight Managers

The ACFP route generation algorithms were designed to optimize their outputs with regard to predicted fuel consumption. The rate of aircraft fuel consumption is contingent upon aircraft gross weight, which in turn is dependent on the weight of the cargo the aircraft is hauling. Furthermore, a variety of routing constraints may or may not be applicable depending on the presence of hazardous material (Hazmat) within a given mission's cargo. Both gross weight and Hazmat involvement are parameters which must be determined based on information obtained from APCC. Unfortunately, neither of these parameters can be reliably specified until a matter of a few hours prior to mission launch. In doing their flight planning tasks, both flight planners and flight managers need to know the facts on these parameters as early as is feasible. In common practice, APCC is not able to provide these facts with any finality until a point in time (circa T-4h to T-6h at the earliest) which is (a) 'tight' with regard to the FM's timeframe for planning actions but (b) later than the flight planners' typical timeframe.⁹

Recurrent References to Final Mission Review at Circa T-6 Hours

During our Phase II KA activities, we made a point to interview members of the Execution Cell to gather information on the culmination of the mission / flight planning process in the execution phase. One point which repeatedly came up was the advisability of doing a comprehensive review and assessment (a 'scrub') of all pending mission records at about 6 hours prior to mission launch. This was intended to identify any lingering problems relating to plans which may have lain unreviewed for several hours.

This approximate T-6h timeframe kept arising in comments and facts surrounding the progression from the planning phase to the execution phase. The following events are some of the more significant ones which cluster around this same temporal waypoint:

- The latest 'deadline' quoted by the flight planners for their finalization of flight plans
- The general forecast timeframe for the latest charts from the WX shop
- Nominal deadline for APCC final confirmation of aircraft weight
- Nominal deadline for APCC final confirmation of Hazmat among the mission cargo
- Nominal time at which FM's undertake their 'paper the crew' tasking for a given mission

It would seem that it is in the vicinity of this T-6h timeframe that various TACC units and roles perceive a sort of 'last chance' juncture at which problems with a pending mission might be caught and conceivably resolved. Similarly, it is not until this approximate juncture that all TACC-provided information (e.g., WX charts, final APCC confirmations on Hazmat and weight) is expected to be finally specified.

⁹ This is not a new issue. During the initial IFM project KA effort (December 2000), FM's were observed to consistently have to wait on APCC to provide them with final or reliable weight specifications and / or Hazmat indications.

It is interesting to note that this approximate T-6h timeframe lies in a sort of 'gap' between the nominal finalization of a flight plan in the flight planning shop and the formally-prescribed 'uptake' of the mission by the Execution Cell. It is the personnel on the 'downstream' side who must deal with the ramifications of any problems (i.e., the Execution Cell staff) who have made a point to do reviews at this time. It is not surprising that the final IFM process typically gets underway at this same time, because it's not until then that an FM can reasonably expect to have all the relevant information on hand. Because FM's are trained to refine (or even generate from scratch) mission flight plans, the IFM process effectively involves a shift in the flight planning function later in the process path to a point where it intersects this seemingly critical timeframe.

All these facts point to a need to support TACC staff at this critical juncture. One might well suggest that some form of organizational adjustment (e.g., role redefinition; procedural changes) might be the most effective way to provide better coverage at this point in the process path. However, such interventions are beyond the scope of our GAMAT mandate, and we shall not pursue their possibilities within this report. Within the framework of current TACC roles and procedures, the most readily available solution path is to provide integrated information assets affording the entire set of relevant planning, execution, and parallel (e.g., DIP, APCC) staffers the ability to obtain and maintain situation awareness on the status of a pending mission.

Collaborative Information Technology (IT) Issues

This section will present those aspects of our GAMAT Phase II work which addressed the tools through which TACC collaborative work was, is, and / or could be conducted. The topics discussed herein will include parallel efforts and developments which affect the IT context for implementing flight planning WCSS.

Ongoing Evolution in TACC Systems

AMC's internal information systems continue to evolve. This evolution has had, and will continue to have, notable impacts on those TACC functions upon which we focused in our Phase II work. The primary developments having a bearing on our subject matter include:

- *GDSS-2 Development.* The evolution of GDSS into GDSS-2 is more than a major upgrade. GDSS-2 will in effect be a whole new system, with new features and an overall configuration distinct from its predecessor. Because GDSS-2 is still in the process of being developed and delivered, our Phase II design concepts were generated without regard to specific features of GDSS-2.
- *ACFP Development.* The ongoing evolution of ACFP had already become something of an issue with the flight planning staff. When we did our initial flight planning KA in December 2002, we were told that the flight planning shop was deliberately using ACFP 2.5 (rather than the already-available ACFP 3.0) owing to a shift in certain features and functionalities with the newer version. This hasn't exactly been welcomed, because although the version 3.0 features are more convenient

for perhaps 90% of the users (most of whom are not in the flight planning shop), who currently perform only about 10% of the overall flight planning work.¹⁰

- *F2 Database Evolution.* The F2 Database is the repository for route specifications available for flight planners' subsequent use. During Phase II there was a persistent question as to how and in what form the F2 Database (or an equivalent repository capability) was going to be carried forward. This made for uncertainty with regard to (e.g.) the prospects for future route specification protocols and formatting, accessibility to the new repository, and other such factors.

'Blind Spots' in Current TACC IT Support

The relative compartmentalization of TACC functions and personnel is reflected in a measure of compartmentalization in the IT support tools provided to and / or use by a given role or unit. As of Phase II, only the flight managers (and / or anyone else) using the IMT Dashboard could claim to have persistent access to both a summary display of mission status parameters and automated support for alerts and warnings on pop-up conditions inimical to mission viability. Without this capability, TACC staffers may have to proactively access one or more IT assets to ascertain current mission parameters 'as planned' and / or additional data necessary to evaluating continued plan viability.

The result is a situation in which TACC staffers are expected to maintain situation awareness over a multi-dimensional problem space within which relevant variables / factors are mutually constraining. The absence of a 'one-stop' visualization or other display affording them comprehensive inspection of these mutually-constraining factors individually, much less as a composite, is one of the key deficiencies in the current TACC IT infrastructure.

The reason this constitutes a deficiency is that the current situation not only facilitates, but practically mandates, certain 'blind spots' along the TACC mission operations process path. By 'blind spot', we mean situations in which TACC staffer A lacks visibility (or ready access to visibility) on parameters or decision factors such as:

- Proactive modifications to an entire plan made by peer staffer(s) B (C, D,...) within TACC itself;
- Proactive modifications to one or another subsidiary plan element (e.g., DIP's; entry / exit times) enacted by peer staffer(s) B (C, D,...) within TACC, and having 'cascade' or derivative negative effects on staffer A's current object of work;
- Proactively-induced constraints or constraint-inducing conditions (e.g., denials of proposed plans on review; NOTAM's) deriving from actions by external parties (e.g., ATC); and / or
- Changes in status or prospects in the operational environment (e.g., weather, MOG) of which staffer A has no knowledge.

¹⁰ Source: KA visit to XOCG, December 2002.

Incorporation of NOTAM and DIP Data

Our GAMAT Phase II effort was not the only project examining IT capabilities of relevance to the flight planning shop and the flight planning process. There were two other efforts being pursued by BBN contractors under the aegis of integrated flight management advanced technology demonstrations (ATD's). As our Phase II work got underway, we kept our eyes open for opportunities for linking into these two external projects.

One of these projects was the development of a prototype DIP 'lead time generator' tool.¹¹ This application was intended to calculate the 'lead time' pertaining to a prospective DIP needed for a given nation. This is important to mission / flight planning because DIP processing must be done with respect to predetermined timeframes which may end up being the deciding constraints on whether a mission or flight plan can be (or still is) feasible. At the present time, there's no reliable method of ascertaining DIP lead times without checking information in the *Foreign Clearance Guide (FCG)*. The FCG is available in the form of hardcopy manuals situated in the DIP shop. This means that checking on DIP lead times requires personal contact (including email or other messaging) and hence delays a planner's continuation of his / her work. Ready access to DIP lead time data would permit planners to quickly ascertain whether or not it is possible to obtain DIP clearances in time for a planned sortie.

The second project was an initiative to prototype a Notice to Airmen (NOTAM) tool. Currently, planners and other personnel must proactively navigate to a website and browse to find NOTAM's applicable to a given airfield. This is time-consuming, burdensome, and guaranteed only to provide the user with data posted as of the time of his / her inquiry. The prospective NOTAM tool would monitor NOTAM's as they were made available and alert TACC users on new NOTAM's having significance with respect to missions being planned and executed. This capability would relieve TACC staffers from both (a) the mandatory burden of proactive searching and (b) the prospect of being 'blindsided' by a NOTAM posted after one had last checked the online repository.

By the close of our Phase II effort, both these projects had made significant headway on their respective tasks. This meant that we could reasonably design WCSS concepts which included reference to readily-available DIP and NOTAM data. The WCSS design concepts introduced and discussed later in this report were therefore tailored to accommodate the products (extant and/or prospective) from these parallel efforts.

Reconfiguring our Suite of WCSS Design Concepts

The GAMAT Phase II effort represented the fourth consecutive project in which AFRL researchers had studied TACC operations and prescribed innovative design concepts. The foci and the products of these earlier projects are summarized in Table 1.3-5 below.

¹¹ This effort was labeled the 'Foreign Clearance Guide Project'. The software application developed in the course of the FCG Project is labeled the 'ACT' (Automated Clearance Tool). (Cf. BBN, 2003, July). Subsequent allusions to this prototype will generally cite it as 'lead time generator' or 'lead time calculator' - the two labels most commonly applied during our Phase II work. This lead time element is a component of the overall ACT package as described in AFRL's SAB poster of December 2003 (AFRL, 2003, December).

Table 1.3-5: Overview of Subject Matter and Design Concepts: FY99 - FY02

PROJECT	SUBJECTS STUDIED	DESIGN CONCEPTS
HISA FY99-FY00	<ul style="list-style-type: none"> •Channel mission planning •MOG 	<ul style="list-style-type: none"> •Port Viewer¹ •Conflict Summary •'Smart Lieutenant' •Structured Listing of Pending Missions to afford SA over the pending workstream²
IFM FY01	<ul style="list-style-type: none"> •New integrated flight management (IFM) mode of work •Flight Managers (FM's) •Utility of IMT Dashboard 	<ul style="list-style-type: none"> •Mission Summary Display (concise 'to-do list' with alert cues) •Flight Planning Palette³
GAMAT Phase I FY01-FY02	<ul style="list-style-type: none"> •WX forecasting and WX support to TACC •WX 'back' and 'front' shops 	<ul style="list-style-type: none"> •GWM-WCSS⁴ •Sortie Palette⁵

¹ Multiple prototypes and deployed applications based on the original Port Viewer concept have been produced since 1999. Additional labels for these descendants of that inaugural HISA product include: 'MOG Tool'; 'MOG Viewer'; and 'HISA Tool'.

² This concept would later be refined and recommended anew in the form of the Mission Summary Display in FY01's IFM project.

³ The Flight Planning Palette was introduced as a paper concept in the IFM project's final briefing (March 2001). As we learned in FY03, the FM staff had accepted this recommended concept and taken action to have it developed using local resources. The result - termed the 'Sortie Manager' - is now an application available for use by the FM's.

⁴ The GWM-WCSS was also known (at various times and by various people) as *Weather Management Toll (WMT)*, the 'Weather Tool', etc. The original prototype (developed and refined by Dr. Ron Scott and his BBN colleagues) has become a deployed application within TACC. As such, the GWM-WCSS is the sole example to date of an AFRL team's prototype which has itself migrated into deployment (as opposed to being re-implemented for deployment).

⁵ The Sortie Palette developed in the GAMAT project was an adaptation of the IFM project's Mission Summary Display concept implemented as an adjunct to the GWM-WCSS.

As illustrated in the table, each of these prior three projects focused on a particular position or function within the overall TACC operational setting. As a result, each of the design concepts generated within these projects ended up being tailored to the relatively narrow context each project's objectives and knowledge acquisition afforded. Nonetheless, each of the concepts has been carried forward toward deployment and daily use - some still within the narrow scope of their original presentations, and some in relation to the more general scope of application which had been intended originally. More specifically:

- HISA's Port Viewer was originally one of three 'viewers' comprising a comprehensive mission visualization tool. It was extracted from this larger set and tailored to address the MOG problem which our TACC customers specified as our research focus. In its various (but relatively unvarying) incarnations, this visualization tool has evolved into a general purpose 'gadget' employed by more than one role within TACC.
- The IFM project's Mission Summary Display was conceived and recommended as both (a) a specific remedy to on-screen visual overload problems identified with the IMT Dashboard and (b) a general top-level situation awareness aid of general utility to all involved in TACC mission processing operations. After the close of the IFM project, this concept was carried forward as (a) a specific display option to be implemented in the oncoming GDSS-2 application and (b) a general mission SA aid associated with the specific tool developed for the WX staff.
- The IFM project's Flight Planning Palette was not carried forward for prototyping in subsequent AFRL projects. However, the intended users (the FM's) took it upon themselves to pursue the concept, and they succeeded in getting it developed locally in the form of what's now called the 'Sortie Manager'.
- The WCSS-GWM prototype has evolved into a general purpose WX visualization aid which has been deployed for use by TACC staffers outside the population of WX staffers for whom it was originally designed.

These examples illustrate that even though our earlier recommendations were framed with regard to one or another narrowly-delineated context, they were always intended to be more generally useful. So long as we continued to focus on a particular position or function, our design and prototype products could be generated with sole regard to the particulars of the context at hand and not the generalities of TACC as a whole. In this most recent project, we finally had to confront the relationship between the specifics of our design concepts and the requirements of supporting multiple (or all) TACC roles and functions comprising the mission processing operations.

The GAMAT Phase II effort marked the first of our four projects to date in which the AFRL team was asked to consider the overall suite of IT support tools available to TACC in light of the overall TACC organization, work process, and workflow. This more general scope of consideration required some adaptations in the number and the details of our suite of WCSS design concepts. These adaptations became necessary because the 'granularity' at which our earlier design concepts were framed was narrower than the 'granularity' at which we now had to assess the concepts' viability with respect to this more general scope.

As a result of this assessment, it was determined that the basic set of capabilities provided in our earlier prototypes and concepts was still viable for overall TACC operations. However, some of the capabilities were more 'generic' than may be evident in their current associations with one or another specific position, deployed functionality, and / or prototype. The implication was that some features or capabilities needed to be re-framed and reallocated into more general forms as we expanded our scope of consideration from individual units to all of TACC. A summary of the necessary adjustments as of Phase II is given in Table 1.3-6.

Table 1.3-6: Adapting Prior WCSS Capabilities to Address TACC-Wide Operations and Team Collaboration Requirements

CAPABILITY	CURRENT STATUS	ADAPTATION REQUIRED
Port / MOG Visualization	<ul style="list-style-type: none"> Currently provided by multiple MOG / Port Viewer prototypes and applications 	<ul style="list-style-type: none"> None (for MOG purposes) <i>Rationale:</i> Because MOG is a discrete issue, there is no problem in maintaining a distinct MOG-specific visualization tool
Summary Workstream Situation Awareness	<ul style="list-style-type: none"> Currently demonstrated in the Sortie Palette element associated with the GWM-WCSS Non-WX-Shop team members must monitor the pending workstream via (e.g.) IMT or GDSS. 	<ul style="list-style-type: none"> Decouple the Sortie Palette from its current placement within the GWM-WCSS Establish the Sortie Palette (or equivalent) as a discrete application / aid within an overall TACC collaborative support suite Elevate this workstream aid to universal access across the TACC team
Geospatial Visualization	<ul style="list-style-type: none"> Currently provided in the GWM-WCSS prototype Offers composite visualization for weather and route / mission elements Current prototype is tailored to WX needs and incorporates some features / priorities peculiar to WX shop 	<ul style="list-style-type: none"> Migrate the general or basic visualization capabilities to a discrete application provided a wider population of users Decouple any WX-specific features or options from this more generic prototype Specify the layers and options (analogous to those provided WX staff already) which need to be prioritized for flight-oriented visualization
Single Flight Planning Palette / Portal	<ul style="list-style-type: none"> Currently available to FM's in the form of the locally-developed Sortie Manager Some among the implemented set of features and options are peculiar to FM needs and functions 	<ul style="list-style-type: none"> Generate a more generic version of the Sortie Manager application Decouple the FM-specific options and features for this more generic prototype
DIP Status for a Given Mission	<ul style="list-style-type: none"> Currently available if one can find it in the free-form text stored in the given mission's Logbook (DAP) records Current BBN ACT Tool provides prototype DIP processing tool, but doesn't provide general SA on DIP's to other TACC team members 	<ul style="list-style-type: none"> Generate a design concept for a generic DIP status display providing SA and master caution panel functions with respect to diplomatic clearances <i>NOTE:</i> This generic SA aid neither conflicts with nor invalidates the functionalities represented by the ACT Tool. The DIP planners still need a detailed tool such as the ACT.

The adaptations cited in Table 1.3-6 don't invalidate the functionalities that our AFRL (and parallel) teams have generated and demonstrated in projects to date. Instead, the adaptations consist of 'repackaging' these functionalities to afford a wider scope of deployment in support of the overall TACC operational team. Phrased a different way, the functionalities developed so far constitute a somewhat piecemeal approach to identifying and mitigating TACC needs. In moving forward to consider the entirety of the TACC operational team and their joint needs, we will necessarily have to redefine which functionalities are to be associated with which positions and roles. By and large, this is a matter of generalizing functionalities created with respect to only one such position / role and recasting them in broader terms.

The specific outcomes of this Phase II reorientation will be presented in Chapters 1.5 and 1.6, where we shall introduce and discuss the WCSS design concepts generated during GAMAT Phase II. In accordance with our assigned focus, these concepts will be framed with primary regard to the flight planning function (broadly interpreted). Before moving on to Chapters 1.5 and 1.6, we shall review and discuss the specific TACC role / position upon which we focused during Phase II (the flight planner) in Chapter 1.4.

1.4 Analysis of TACC Flight Planning Work

This chapter will present those aspects of flight planning (as a task and a process) that were (a) specifically cited during our Phase II GAMAT KA work and (b) judged relevant to our Phase II focus on flight planning. Some of these items are indicative of problems for which WCSS design intervention may be appropriate. Others are clues to current or prospective features of the TACC flight planners' role, functions, and / or work ecology. Examination and consideration of the issues outlined in this chapter led to our selection and prioritization of features worthy of being implemented in our recommended WCSS interventions.

Scope of Flight Planners' Tasking and Presumed Knowledge

Flight planning is a complex decision making process which must attempt to account for a wide variety of factors, many of which are undetermined or indeterminable at the point the planner really needs to know them. The number and variety of these decisive factors induces a daunting scope for the knowledge and situation awareness an effective flight planner is expected to have. Adding to this is the scope of oversight responsibilities assigned to TACC's flight planning staff. They must continuously support Air National Guard and Reserve missions in addition to USAF ones. They must provide on-demand planning support for commands (e.g., PACAF) who typically do their own flight planning.¹² They serve as the presumptive 'fall-back' planning support unit for tough cases.

All this means there is little hope for precisely circumscribing the flight planners' expected workstream and / or the elements critical to processing one or another 'case' (i.e., mission) within that workstream. Beyond this, here is little hope for precisely prescribing the range of knowledge (both abstract and experiential) necessary for a flight planner to be effective. This explains the fact that significant hands-on experience is claimed to be required to get a new flight planner 'up to speed'.¹³ This also explains the fact that seasoned flight planners are ascribed a degree of personally accrued 'expertise' not widely ascribed to other TACC positions.

¹² PACAF normally does all its own flight planning for missions executed within its AOR. However, for missions and / or mission assets outside this AOR, PACAF routinely calls on TACC's flight planners to get involved. (Source: KA with XOCZ, December 2002)

¹³ Specifically, one SME claimed it took 2 months of OJT plus 6 - 12 months of daily work experience to achieve proficiency as a flight planner. (Roth: 2003, March)

Comments and Analysis:

Flight planners, like flight managers, are expected to decide and document a coherent and feasible plan in the context of a very messy and dynamic decision space. Both the missions they are tasked to plan and the factors impinging upon those missions often rely on information 'over the horizon' from the flight planning shop, and even outside the scope of TACC itself. Owing to their status as 'fallback' experts, their prospective workload is unpredictable. Owing to their centrality in the TACC mission processing path, their workload (however daunting on any given day) is both unavoidable and top-priority. Owing to the fact that many of the factors they must evaluate are dynamic and outside the scope of both their ken and their control, they are often forced to operate in a sort of reactive mode. These general points contribute to a picture of the flight planners' role as being susceptible to stress and burnout.

Progressive Shift toward Coordinated Look-Ahead

In our first Phase II KA visit focusing on flight planning (December 2002), we were advised that the flight planning shop had recently succeeded in changing its mode of operations with regard to timeframes and situation awareness over its workstream. In the past, once flight plans were generated they were not revisited until and unless some exception arose. By the time of the December 2002 visit, it was stated that the flight planners were now conducting proactive reviews of pending flights / flight plans up to 4 days in advance of launch.¹⁴

Comments and Analysis:

This migration to a more proactive review is a good thing, to be sure. It indicates recognition of the fact that organized look-ahead can catch and resolve problems before they become intractable. It's also important to note that this development mirrors concerns about doing a preliminary / prospective 'scrub' of pending missions / flights that were consistently expressed by SME's we interviewed from the Execution Cell.¹⁵ It appears that the flight planning shop's move to institute such a proactive review was done independently of any action on the part of other relevant units. It also appears that there is a coalescing consensus in TACC to the effect that some form of proactive review is needed in the hours leading up to mission launch.

¹⁴ Source: KA visit to XOCZ, December 2002.

¹⁵ Source: KA with Execution Cell staff, October / November 2003.

Relationship between Flight Planning and the Emergent IFM Process

In theory, the move toward *integrated flight management (IFM)* and the arrival of dispatcher-style *flight managers (FM's)* can and will reduce the load on the traditional flight planning shop. The IFM concept is still in the process of being implemented over 3 years after being introduced. As of Phase II, it was still the case that the vast majority of TACC missions were being handled via the traditional means. As of December 2002, it was claimed that the IFM process accounted for no more than 8% of the entire TACC mission throughput.¹⁶ The figure given us by flight manager SME's in June 2003 was 15 - 20% of all missions.¹⁷ Though substantially higher than the estimate given by the flight planner SME, this figure is still a minority of overall TACC mission throughput.

Although the new cadre of FM's is trained to generate and refine flight plans just as the traditional flight planners do, the flight planning shop still attempts to 'pre-process' IFM missions in the sense of generating initial ACFP specifications to be stored for subsequent FM review and usage. This gives the FM something to work with when he / she gets started on a 'paper the crew' task, typically 4 to 6 hours prior to mission launch. According to comments made during our December 2002 KA visit, it would appear the FM's commonly end up re-running the flight plans during this later work.¹⁸

Comments and Analysis:

It is not surprising that the flight planning shop remains engaged in the minority workstream destined for FM processing. TACC is, after all, still in the midst of its long ramp-up into the new IFM way of doing things. However, there remain two general issues that may bear further scrutiny in evaluating whether or not the current interplay of flight planners and flight managers is working as well as it can.

The first issue concerns the training and capabilities of the FM's with respect to the flight planning function. Although the FM's are trained to use ACFP (which they access via the Local User Interface (LUI)), they may still lack the depth of expertise the flight planners have. In our December 2002 KA visit to XOCZ, there were multiple SME points indicating that facility with ACFP requires significant experience. Examples of such points included:

- The fact that XOCZ continues to consider 'pre-processing' of IFM missions an active part of their workstream
- Multiple allusions to XOCZ serving as the backup / fallback source of flight planning expertise available to the FM staff
- Multiple statements to the effect that expertise with ACFP is a key factor in the quality and efficiency of flight planning¹⁹

¹⁶ Source: KA visit to XOCZ, December 2002.

¹⁷ Source: Roth (2003, July)

¹⁸ Source: KA visit to XOCZ, December 2002.

¹⁹ For example, there was a statement made in our December 2002 visit to XOCZ to the effect that ACFP could be 'junk' if you didn't know how to use it.

- Allusions to the level of expertise needed to identify the 1 or 2 truly feasible routing specifications out of potentially hundreds (or, in some cases, thousands) ACFP is capable of generating
- Allusions to the effect that ACFP can be a cryptic application whose use requires recourse to tech support²⁰

It comes as no surprise that (as a class) the flight planners are better able to use ACFP (and, by extension, to produce effective flight plans) than the FM's. By the same token, one might well question the extent to which the current situation provides FM's with sufficient in-depth ACFP usage to allow them to rise to the flight planners' relative level of such expertise. The current pre-processing of IFM missions by the flight planners constitutes only a portion of their workload. Assuming the TACC workstream shifts toward the IFM model as planned, any deficiencies in FM expertise will become more problematical as this shift proceeds.

The second issue concerns the viability of the flight plans the flight planners generate and store for subsequent use by the FM's. An FM typically begins his / her 'paper the crew' activities around 4 - 6 hours before mission launch. It is typical for a flight-planner-generated flight plan to be 10 or more hours old at this point in time.²¹ As a result, FM's frequently (and, according to some - typically) re-run flight plans (via ACFP) during their pre-launch work.

It should also be pointed out that the typical accretion time of a flight plan generated by a flight planner is too soon to have reasonably been informed by the WX shop's forecast charts (whose predictions extend about 6 hours into the future). This means that the emergence of problematical weather conditions could easily make a flight planner's product obsolete, thus forcing the (presumably lesser-experienced) FM to have to back up and start the flight planning from scratch. Naturally, there's little that can be done to assure that the flight planner's first cut is necessarily feasible as far as weather is concerned. Instead, the point is that pop-up WX problems can force a 'crunch situation' in which the personnel having to react (the FM's) are not the personnel best equipped to do rapid re-planning.

Flight Planning Work as a Two-Stage Process

The flight planning shop's work can be seen as breaking down into two distinct phases or stages. The first is the generation of initial (ATC-submittable) route specifications based on ACFP. The second is the editing and re-planning done in light of ATC feedback or even rejections. This second stage can extend into multiple submit / revise cycles.²²

²⁰ At one point early in our December 2002 visit, a SME noted that 'even 10-year veterans' must sometimes fall back to contractor tech support to figure out what ACFP is doing and why it's producing the results it does.

²¹ In our December 2002 XOCZ visit, the age of a flight planner's product at the point an FM takes it up was stated to be in the 10 to 14 hour range.

²² Source: KA visit to XOCZ, December 2002.

Comments and Analysis:

Although both these flight planning task phases can take arbitrary lengths of time, it is the second (ATC submit / revise) that is most 'open-ended' and hence unpredictable. For one thing, there's no sure way to predict whether ATC will approve a given plan. For another thing, the decision space is so vast and dynamic (e.g., via NOTAM's) that there's no stable basis for even guesstimating the odds for approval of any given plan on any given day. This second stage is also the one that is more potentially time-critical. Owing to its coming after the ACFP generation stage, it's conducted closer to deadline. Owing to its termination criterion being external to TACC (i.e., in the form of eventual ATC approval), this is the stage more likely to leave planners (and other TACC staffers) 'in the dark' while launch time approaches.

There are, of course, no interventions within TACC which would directly influence the rapidity or leniency of ATC decisions. Phrased another way, TACC's flight planning staff will always be vulnerable to being 'jerked around' whenever ATC decides a given flight plan is unacceptable or unfeasible. This means the most probably constructive approach to WCSS intervention would emphasize means for facilitating more efficient re-planning as the need for such re-planning occurs.

Flight Planners' Reliance on Locally-Accreted and Locally-Maintained F2 Database

One of the most striking aspects of current flight planning operations is the fact that the flight planning shop relies very heavily on the F2 Database - a critical data resource whose contents are generated, accreted, and maintained locally within the flight planning shop itself. To be sure, other 'shops' or units within TACC rely just as heavily on various data assets. However, there is no other such unit for whom the stewardship of such a critical data resource is a task assigned to the unit itself. It is an indication of the complexity of the flight planning decision space that such a resource is necessary. It is an indication of the criticality of the flight planning function to overall TACC operations that such a resource was established. It is an indication of the relatively high degree and depth of 'expertise' associated with the flight planning task that this resource is as voluminous as it is.²³

Comments and Analysis:

The combination of decision data complexity and procedural reliance make the F2 Database (and / or some equivalent routing knowledge repository) a critical resource for the flight planners. Any innovations undertaken in support of flight planning must account for the contents and utility of the F2 Database. This does not mean that the current form and capabilities of the existing F2 Database must circumscribe the extent of future routing knowledge support. We identified one particular way in which the current F2 Database could be extended or improved to better support flight planners. This is the topic of the next subsection.

²³ During our December 2002 KA visit to XOC we were told that approximately 6500 route records are stored in the F2 Database.

Limitations in Employing the F2 Database

The importance of the F2 Database to the flight planning process contrasts with the relatively narrow way it must be employed. The records are indexed via 'city-pairs' - dyads specifying the arrival and departure ports defining the prospective flight's end points. Users must index and search the records solely on the basis of these city-pairs. This means that an F2 query may produce several different route specifications for getting from departure port A to arrival port B. Once a route specification is chosen for refinement into a flight plan for a given mission, the flight planner must manually edit it as a text document.

The primary inefficiency in the current F2 arrangement relates to the structure of the route specifications stored therein. They are essentially 'all or nothing' records of entire routes linking city-pairs. They cannot be readily decomposed and edited in terms of their subsidiary route segments. Neither can the users index into the F2 Database on the basis of a particular such segment. This means that obtaining a precedent specification for a given segment of an overall route requires laboriously scanning through an arbitrary number of complete end-to-end route specifications. This makes tweaking an existing flight plan (e.g., during last-minute replanning) more labor intensive and inefficient than it might be. In addition, this all-or-nothing characteristic of the current record structure induces a requirement that all records be evaluated and accreted to the database as non-decomposable wholes. This makes for considerable redundancies among stored route specifications (i.e., they vary only marginally by differences among features of particular segments or sets of segments).

Comments and Analysis:

The redundant 'all-or-nothing' F2 Database records induce considerable overhead for searching, manipulating, and maintaining this critical flight planning resource. This excessive overhead has numerous aspects and corresponding deleterious effects such as:

- Increasing nominal search time to locate a viable candidate route specification
- Increasing the minimum amount of text that must be scanned to assess viability of any given candidate record
- Increasing the time required to review, compare, and select among route specifications returned on a given query
- Increasing the amount of text that a planner must contend with to make a change at any level of granularity
- Increasing the cognitive burden on the person searching the database and reviewing the records returned
- Increasing the risk of decision errors in evaluating, comparing, and selecting among the candidate route specifications

- Increasing the number of records that must be reviewed for modification with each DAFIF update cycle (every 28 days)
- Increasing the risk of errors in evaluating which and how many records need to be updated with each DAFIF cycle
- Increasing the cognitive and procedural burdens for determining which route specifications may reasonably be retained and which may be deleted

In light of these factors, the GAMAT team proposed the introduction of a 'two-level' or 'double-level' capability into the next-generation F2 Database (or its equivalent). The two 'levels' connote that there should be two levels of route granularity at which flight planners could index, address, and manipulate route specifications. The first would be an overall route linking a city-pair (as is currently implemented). The second would be a finer-grained level at which subsidiary pieces ('segments') of this overall route could be indexed, addressed, and manipulated.

We had conceptualized such a bi-level approach to route specifications as a result of our early GAMAT Phase II KA visits to TACC. We noted that whenever a complete 'canned' route specification did not fit a planner's current purposes, he / she would modify the segment(s) of that routing spec necessary to transform it into one better suited for the current mission or circumstances. In addition, there were SME allusions to key pieces of rationale for a given routing spec being predicated not on the entire route, but also upon conditions and / or constraints pertaining to a given route segment.²⁴ Beginning with our June 2003 KA trip to AMC (cf. Roth: 2003, July), we began actively probing the SME's on the prospects and perceived utility of addressing routes by segments. The response was uniformly positive to such a prospect.²⁵

Limits to Flight Plan Revisions without Re-Running ACFP

ACFP is the primary tool for generating routing specs for a new flight plan. The output from ACFP is a textual routing specification which the flight planner may edit or otherwise tweak as he / she sees fit. Once the flight planner is satisfied with the route specification derived from ACFP, he / she can subsequently submit it to air traffic control (ATC) for review and approval. If ATC doesn't approve the routing 'as is', the flight planner may or may not be able to revise the current specifications without going back to ACFP and essentially starting over.²⁶

²⁴ Cf. Roth (2003, March)

²⁵ For example, the SME tasked to oversee and maintain the existing F2 database proactively suggested that the ability to address routes in terms of segments would be a big help in a number of ways. (cf. Roth, 2003: October)

²⁶ Source: KA visit to XOCZ, December 2002.

Comments and Analysis:

It's not clear what criteria can or must be invoked to ascertain whether a flight plan can be fixed in its current form versus being re-done by falling back to ACFP. The relatively simplistic and time-consuming process of dealing with route specifications as raw text makes either course of action slower and more susceptible to error than it should be or could be. This text-only situation necessarily makes the review and decision tasks more cognitively burdensome, because there are no explicit cues relieving flight planners from having to 'connect the dots' mentally.

Based on observations of flight planners working through the route specification process beginning with ACFP, it appeared that the post-ACFP editing was more time-consuming than working with ACFP to get the initial routing specs in the first place. Add to this the necessity of (re-) orienting oneself to a pending work product (the submitted flight plan) the details of which he / she may have forgotten, and it seems clear that dealing with an ATC rejection (either major or minor) can take up as much time as generating the plan that was originally submitted.

Even more to the point is the fact that a route string / specification is treated as a whole. This begins with the generation of a routing specification from ACFP, where the sole means of denoting the desired route is a 'city-pair' (i.e., designations for the end points). ACFP then generates a candidate set of routes between these end points, each one of which is a unary collection of text descriptors. This means that decisions about a route's viability generally have to be evaluated on an 'all or nothing' basis (i.e., it's either 'all good' or 'junk'). The only extent to which flight planners may circumvent this all-or-nothing constraint is to go to the trouble of delving into the textual route string and manually edit it into something more viable.

All these foregoing points could be made less problematical if flight planners were capable of addressing route specifications as sets of modular subcomponents (i.e., 'segments' comprising the entire route). A coherent schema for doing this would permit:

- Initial ACFP (or equivalent) route specifications capable of being addressed in a more modular (and hence less cognitively burdensome) manner
- An ability to more readily focus in on and modify one or another route 'segment' in realtime
- The ability to index (and hence maintain) the F2 Database (or evolutionary descendant) on a finer-grained basis than is currently possible
- The ability to reduce individual record storage requirements within the F2 Database (or evolutionary descendant) by eliminating the need to record an entire city-to-city route string for each and every variation on the potential routing between those end points
- ACFP (or equivalent automated) generation of route specifications for only those segments in need of replanning (e.g., in light of ATC rejections or other pop-up requirements for replanning)

Issues with Disparate Features among ACFP Versions

It was surprising to learn that different versions of ACFP have distinctly different features, and that these differences made for corresponding differences in the perceived utility of one versus another version of the software. At the time of our December 2002 KA visit to XOCZ version 2.5 was in use, and a version 3.0 was expected to arrive by September 2003. It was stated that 2.5 was the latest version to offer what was termed 'full functionality', and that version 3.0 was already known to offer less than this level of functionality. Perhaps most importantly, post-2.5 versions of ACFP were stated to have dropped the ability to retrieve and reuse past planning products.²⁷

Comments and Analysis:

Any decrease in the range of functionalities provided by a later software release is a curious development worthy of interest. In the case of ACFP, the purported loss of retrieval / reuse capabilities is especially interesting, insofar as the flight planning shop actively attempts to maximize the opportunities to operate by 'precedent' (i.e., by calling up a known route specification and editing it to fit the current mission requirements). Furthermore, in the course of performing detailed flight planning, the flight planners often have to do considerable 'what if' examination of options and alternatives.²⁸ In a decision space as large and multi-faceted as flight planning, the number of options available for review is a positive aid in managing complexity.

Issues with Availability of Relevant Information during Flight Planning

Flight planning would be more effective if the initial routing specifications remained viable through to the point of mission launch. Given the number of things which can 'clobber' a flight plan, this naturally must remain an ideal instead of a practical goal. Most of the factors which can invalidate an initial flight plan are not fixed by the point in time when the flight planner generates his / her 'first cut'. To some extent, however, the attendant risks can be attributed to non-availability of relevant information at that same point in time. In the following subsections we shall briefly note some of the information-specific factors which contribute to the risk.

²⁷ Source: KA visit to XOCZ, December 2002.

²⁸ Source: KA visit to XOCZ, December 2002.

NOTAM's

Notices to Airmen (NOTAM's) are the bulletins issued by (e.g.) airfields advising the aviation community of constraints, changes, requirements, news, etc. Although NOTAM's are not new, there remains no efficient means for checking them. This means that flight planners are hard pressed to stay current on conditions affecting a given mission's ability to use a given location. Flight planners do not currently have an efficient and effective means for checking NOTAM's in the course of their planning tasks. As a result, it is all too easy for them to unknowingly generate a flight plan destined for re-planning owing to conditions of which they were unaware.²⁹

Weather (WX) Information

Given the advance timeframe in which conventional flight planning is conducted, there is little chance that accurate fine-grained WX forecasts can be made available for flight planners' reference. The typical timeframe for flight planning is 10+ hours prior to mission launch. This exceeds the nominal 6 hours' forecast horizon for the WX shop's most detailed charts.³⁰

Diplomatic Clearances (DIP's)

Any flight passing over other nations has to have been granted diplomatic clearance (DIP) by the given nation(s). The flight planning shop is involved with DIP's only to the extent of requesting clearances on flights for which (a) this has not yet been done or (b) changes in circumstances require re-examination of clearance issues and / or viability. The flight planner has no automated support in maintaining situation awareness on the viability of DIP's. As a result, changes in DIP status may invalidate his / her plans (or plan options) without him / her even knowing about it.

Furthermore, it falls upon the flight planner to identify situations (particularly during re-planning) where changes in the routing or predicted flight scheduling may need to be referred to the DIP shop to see if and how they affect DIP's and /or DIP requirements. This mission-critical / time-critical requirement for reviewing and re-evaluating DIP's is not a minor incidental occurrence. A senior DIP Shop SME claimed that it is typical for the DIP staff to have to see and review a mission up to 4 or 5 times as changes occur prior to execution.³¹

Comments and Analysis:

The flight planner's job is made more difficult and error-prone to the extent that relevant circumstances are unknown to him / her and hence not taken into account. The three primary examples of such key information (NOTAM's, weather, and DIP's) all represent factors which:

- Can invalidate an otherwise-viable flight plan

²⁹ Separate USAF and FAA projects have been undertaken with the objectives of centralizing access to known NOTAM's, affording global access to this compiled data, and even providing timely alerting on newly-accreted NOTAM information.

³⁰ The WX shop 'chartmaker' also generates charts for longer timeframes, but these are progressively less fine-grained and less reliable. The 'second-tier' WX shop charts are supposed to be framed up to 10 - 12 hours into the future. This is little help to the flight planners, who are doing their planning at about the time when these 'secondary' and less-reliable charts are fresh.

³¹ Source: Roth (2003, March)

- Can cause such invalidation at any time prior to, during, or following the flight planner's work on the given mission
- Cannot be directly changed on the flight planner's own initiative
- Cannot be directly changed on TACC's own initiative
- May cost arbitrary amounts of time to resolve, and hence...
- May force last-minute cancellation / postponement of a given mission

Naturally, there's no way to guarantee that these factors and their attendant risks can be completely eliminated as sources of planning risk. However, there is plenty of room for improvement in keeping the flight planners apprised of these factors (vis a vis a given mission) such that:

- Time is not wasted planning a flight that simply can't be done
- Time is not lost learning of changes which require re-planning
- Mission constraints are known (within reason) at the time the flight planner is expected to produce a viable flight plan

Of these three categories, the one examined more closely for WCSS support within the Phase II GAMAT effort was DIP's. This focus was not intended to indicate we had concluded DIP problems are absolutely more important or more critical than those relating to weather and / or NOTAM's. The emergence of unforeseen constraints in any one of these categories can be inimical, or even 'fatal', to a flight plan's viability. All three are 'high risk' for the occurrence of such unexpected constraints, because all three pertain to factors which are beyond the control or precise prediction of TACC itself.

Still, the DIP category recommended itself for further examination based on two factors. First, improved situation awareness (SA) regarding both weather and NOTAM's had become the objects of IT innovation projects in recent times. Our own WCSS-GWM had demonstrably addressed the weather category, and a parallel R&D effort in Phase II was similarly addressing NOTAM's. Efforts to do the same in the realm of DIP's consisted of the recently-arrived Logbook capability and BBN's development of a 'lead time calculator' in a parallel project during Phase II. Both these initiatives represent innovations intended to improve DIP processing capabilities. Neither, however, necessarily improves situation awareness for flight planners on DIP status during the critical period when mission launch is imminent.

Second, it must be pointed out that the context for DIP processing has certain characteristics making it arguably even more constrained a decision space than is the case for weather or NOTAM's. The factors underlying this claim are summarized in Table 1.4-1. As illustrated in Table 1.4-1, it is reasonable to claim that both (a) the practical planning horizon for DIP's is longer than for either WX or NOTAM's, and (b) the potential impact on a flight plan (in terms of area / distance required for correction) is greater. In other words, DIP's is 'higher-risk' in terms of both deadlines for 'getting it right' and the cost of adapting to a change at the last minute.

Table 1.4-1: Comparative Problematicity in WX, NOTAM's, and DIP's

ISSUE	RE: Weather	RE: NOTAM's	RE: DIP's
Deadline for Planning Changes	<ul style="list-style-type: none"> • None - WX issues can pop up any time 	<ul style="list-style-type: none"> • None - NOTAM's can be issued at any time 	<ul style="list-style-type: none"> • T-24h (minimum lead time for DIP request)
Look-Ahead Horizon	<ul style="list-style-type: none"> • 0 - 24 hours into the future (general) • 0 - circa 8 hours into the future (specific) 	<ul style="list-style-type: none"> • 0 - 24 hours into the future 	<ul style="list-style-type: none"> • 24+ hours into the future
Scope of Negative Impact (Geospatial)	<ul style="list-style-type: none"> • Airfield / Location (minimum) • Sub-National Area / Region (maximum) 	<ul style="list-style-type: none"> • Airfield / Location (typically) • Sub-National Area / Region (conceivably) 	<ul style="list-style-type: none"> • Entire nation
Risk: Divert Distance	<ul style="list-style-type: none"> • 10's - 100's of miles (to avoid bad WX; to access airfield) 	<ul style="list-style-type: none"> • 10's - 100's of miles (to feasible airfield) 	<ul style="list-style-type: none"> • 100's - 1000's of miles (to avoid entire country)

This relative risk is compounded by the fact that the DIP Shop may have to review a given mission up to 4 or 5 times by the time it is accomplished.³² DIP workloads are such that the rate of errors (DIP clearance violations) is claimed to run approximately 1%.³³ The incidence of missions cancelled or turned back on account of DIP violations was stated to be on the order of approximately 0.2%.³⁴

Time and gain during our Phase II KA visits we received allusions to the fact that DIP clearances constitute not just a significant constraint on the general mission / flight planning decision making process but also a very problematical constraint on TACC's ability to dynamically re-plan missions and flights as execution time drew nigh. As a result, we elected to include some means for providing situation awareness on DIP status and viability to TACC staffers in both the planning and execution phases of the mission operations process path.

³² Source: Roth (2003, March).

³³ In the March 2003 KA interviews with DIP SME's, it was stated that typically 3 to 5 out of the 500 missions being processed on a given day will have dip violations. (Roth: 2003, March)

³⁴ These incidence figures are drawn from Koth (2003, March). These relative incidence figures don't seem like much in relation to the overall workflow (up to 500 missions per day). However, it must always be borne in mind that even a single mission cancellation represents tens, and perhaps even hundreds, of thousands of dollars lost in mission costs. Add to this the prospect of generating 'cascading' failures as one failed mission negatively impacts parallel / subsequent missions, and this cost escalates dramatically.

Workload Associated with Generating Notional Flight Plans

As noted in the chapter on collaboration issues, the flight planner is responsible for the generation of 'notional' flight plans early in the overall mission / flight planning process. This is done to create 'initial sketches' of prospective routes so that mission planners can evaluate options, constraints, and possibilities for a new mission they are trying to plan.³⁵ A notional flight plan also provides the mission planners with the ability to specify those nations for which DIP clearances must be obtained. This enables the DIP shop to get a head start on the time-consuming task of arranging the DIP clearances for the new mission. Furthermore, the DIP shop may request a flight plan specification to aid them in determining DIP prospects and constraints.³⁶ These DIP Shop-requested plans are expected to be more akin to final flight plans (i.e., more details on routing and prospective scheduling) than the 'notional' ones requested by the mission planners. The estimated incidence of DIP Shop requests for flight plans is approximately 20% of the missions being processed by the DIP Shop.³⁷

The general layout of the notional flight planning process is illustrated in Figure 1.4-1. By and large, the mission planners' requests for notional flight plans will come far in advance of the timeframe during which the flight planners are typically doing their detailed flight planning on a given mission. This 'advance' status pretty much applies to the DIP Shop requests as well. Even when the DIP clearance process is undertaken relatively late in the mission process path, it will predate the flight planner's final / detailed flight planning work. Because the DIP shop needs to be processing DIP requests 1 or more days ahead of mission launch, this work must be initiated prior to the flight planners' nominal timeframe for final detailed flight planning (which can run as little as 10 - 12 hours prior to launch).

³⁵ It is not the case that mission planners request a notional flight plan for all pending missions. According to information given us in interviews with mission planners, they first attempt to estimate flight time, etc., using historical data assets (e.g., TACC Fly Time Viewer, CAMPS historical data, Great Circle Mapper). However, these historical data assets are not uniformly applicable, accurate, or up to date. (cf. Roth: 2003, July)

³⁶ Both the mission planners and the DIP planners may request a flight plan from the flight planning shop. However, it is only in the case of the mission planners (who are attempting to ascertain a workable route) that the product generated is termed 'notional'. Regardless of how tentative it may be, a plan product generated in response to a DIP shop request is termed a 'flight plan' (i.e., not a 'notional flight plan'). (cf. Roth, 2003, October). This difference in terminology is more than skin-deep. The DIP planner needs sufficiently detailed information on prospective scheduling and routing (as it pertains to entry and exit points) to be able to effectively take action to obtain the necessary DIP clearances. (cf. Roth, 2003, March) Nonetheless, our notion of allowing planners other than flight planners to generate 'notional' flight plans has been pursued with respect to affording this capability to both mission planners and DIP planners.

³⁷ Source: Roth (2003: July)

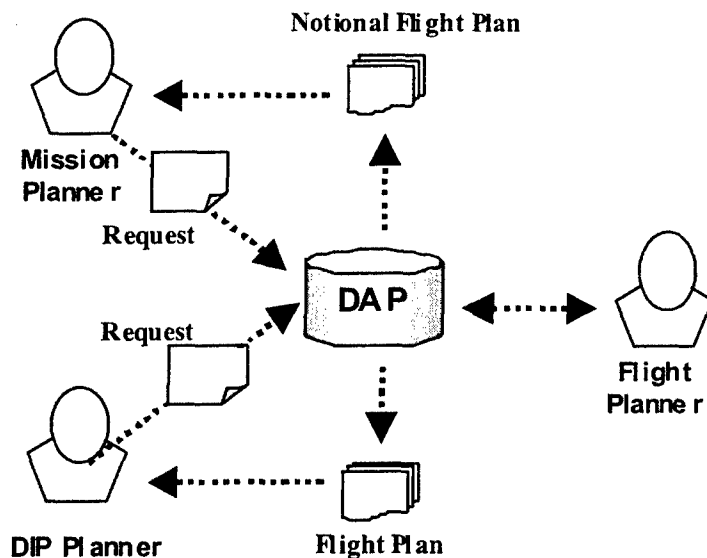


Figure 1.4-1: Conventional Workflow for Notional Flight Planning

Comments and Analysis:

The responsibility for generating notional flight plans naturally adds to the flight planner's workload. In the best case, notional flight planning represents an initial run-through for a route specification the flight planner will refine at a later date. In the worst case, it's a workload completely 'above and beyond' the workstream with which the flight planner will contend for final / detailed planning purposes. Such 'above and beyond' cases include those in which the flight planner has to generate a plan he / she may never see again. Circumstances in which this can happen include:

- Notional flight plans generated for mission planner review, only to be discarded as candidates from the initial mission planning
- Notional flight plans generated as entirely new options for a mission which is being re-planned upstream of the flight planning shop
- Notional flight plans contributing to missions on which the flight planning shop may have no subsequent involvement

During our Phase II GAMAT work, we came to question whether or not these notional flight plans demanded a level of detail and discrimination warranting the personal involvement of the flight planner in each and every case. Our inclination was to configure a WCSS capability (analogous to the capabilities being designed for the flight planners themselves) that would permit the mission planners to generate their own notional flight plans (at least for 'easy' or 'straightforward' cases). We made a point to probe our subject matter experts on this prospect during our October and November KA visits to AMC / TACC. The responses we received (cf., e.g., Roth: 2003, October; 2003, November) were as follows:

- Representatives of the flight planning shop uniformly expressed approval of this idea in general

- The SME's uniformly noted the utility of such a capability in allowing mission planners to designate countries to be overflown, and hence better advise the DIP shop what clearances would be required.
- Owing to the fact that the majority of mission routes were 'standard' (or at least well-known) even offering this capability for such *pro forma* routes would have a significant effect on reducing flight planner workload.
- Some of the support information for offloading notional flight planning has already been made available. The F2 Database data is accessible outside the flight planning shop via a Website, and some outside the flight planning shop (e.g., the FM's) can access ACFP via their Local User Interface (LUI).
- By the same token, the selection of routes and route details can be contingent on a variety of factors which are either subtle or subject to dynamic changes. It is not reasonable to assume that the other units given access to notional plan generation would or should be expected to know and / or keep track of such things.
- All flight planning shop representatives cautioned that some measure of caution would have to be recognized so as to make these other staffers' notional flight plans 'dummy-proof'.

These last two points raise a cause for additional concern and consideration in assessing the prospects for alleviating the flight planners' notional flight planning workload. There is an important composite tradeoff that needs to be evaluated. On the one hand, it is fairly clear that having mission planners generate their own notional flight plans might aid TACC team efficiency by:

- reducing time flight planners must divert to notional flight planning
- reducing time lost to communications, tracking, and follow-up overhead related to the request transactions (between mission planners and flight planners) themselves
- reducing the total time a mission planner has to wait from starting his / her mission planning to requesting DIP clearances
- promoting somewhat more 'lead time' for the DIP shop to receive and begin processing a mission's DIP requirements

On the other hand, it is conceivable that such a capability could actually degrade TACC team effectiveness and efficiency if it led to:

- diminished quality in the notional flight plans generated (relative to subtle decisions currently made by the flight planners)
- increased time taken by the mission planners (relative to the flight planners) in figuring out and deciding the notional flight plan parameters

- an increased number of questions or requests for information raised by the DIP shop in response to mission planners' notional flight plans³⁸
- a higher number of substantial 're-plans' the flight planners have to do at their downstream detailed planning stage
- a higher number of planning failures (forcing mission cancellations or delays) owing to more numerous such 're-plans' at that late point in the process path

In the final analysis, we elected to proceed with the concept of affording mission planners the ability to generate and assess their own notional flight plans. The mitigating factors which overrode the cautionary factors cited above included:

- the fact that the WCSS concepts needed to support the mission planners (on notional flight planning) were not categorically distinct from the concepts we proposed to generate to support all planners
- these more general WCSS concepts were not being constrained or unduly modified to suit the particular purposes of mission planners doing notional flight plans
- these more general WCSS concepts were independently justified on their own merits, meaning that any eventual negative evaluation of mission planners' usage for notional planning would diminish, but not invalidate, those concepts
- the consensus among our SME's that such a capability could be an improvement (subject to the cautions noted above)

Our approach was to facilitate a process path within which the mission planners were primarily responsible for generating notional flight plans through direct interaction with a new flight planning WCSS. This would equip them to perform their mission planning without having to interrupt flight planners for such a notional specification. This notional plan could then be forwarded to the DIP planner with the mission planner's initial request to initiate DIP requests. The general layout of this concept is given in Figure 1.4-2.

³⁸ As noted earlier, the DIP shop treats advance routing specifications requested of the flight planning shop as 'flight plans' rather than 'notional flight plans'. There is an insinuation that the DIP shop expects something more substantial, reliable, and maybe even more detailed, than the mission planners might routinely expect. In the event that DIP Shop-requested plans are not as 'notional' as those requested by the mission planners, one could conceive of the DIP Shop continuing to 'ping' the flight planners for route specifications regardless of who generated the initial 'notional' plan. Such a trend would at least partially negate the flight planner workload reduction we are seeking to induce.

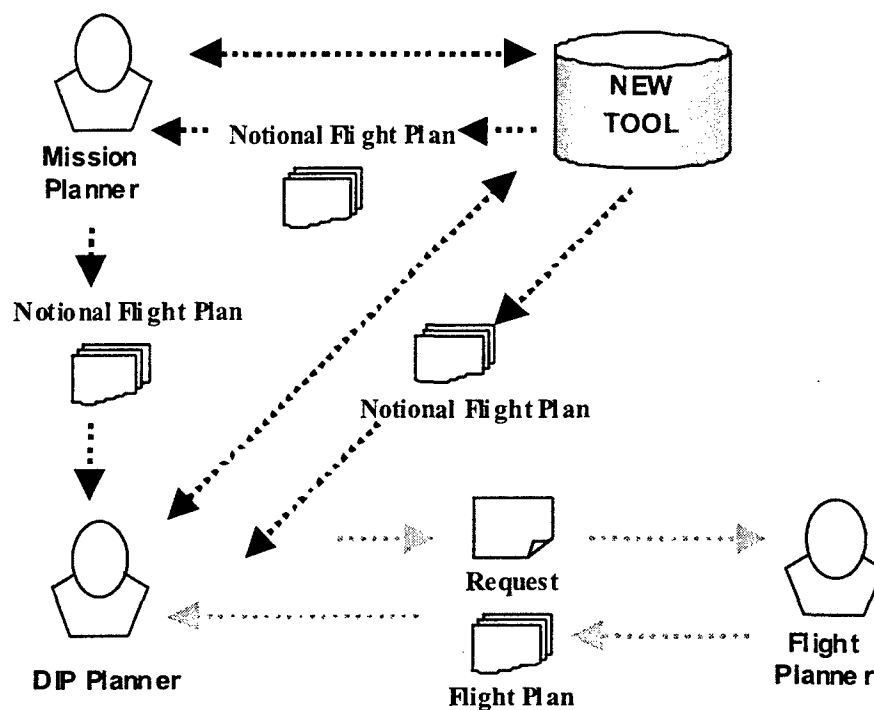


Figure 1.4-2: Procedural Concept for New Notional Flight Planning Layout

The primary innovation is to provide WCSS support allowing the mission planners direct access to flight planning tools. This access could conceivably / secondarily be made available to DIP planners should they need to perform 'what-if' or other relatively simple plan visualizations. This is not meant to imply we are eliminating the current direct request 'channel' between DIP planners and flight planners. The DIP planners' requests to flight planners are typically for something more detailed than the notional products the mission planner needs. As a result, we presume there will continue to be a procedural path by which the DIP planner can continue to request plan specifications more detailed than what they can generate directly with the notional planning tool.

Utility of Graphical Visualization in Flight Planning

The manipulation of a route specification is done as an exercise in text processing. This requires a considerable cognitive burden on the flight planner, because he / she must:

- mentally map the geo-spatial dimensions of the prospective flight onto the text displayed
- mentally map any modifications to the current text set onto an imagined geo-spatial context
- maintain a working awareness of any options or variations on geo-spatial implications and ramifications in his / her imagination during the course of a planning session

In other words, the flight planner is personally responsible for unaided and cognitively burdensome realtime 'visualization' of a flight plan with respect to geo-space. Once a flight or route specification is (textually) laid out and recorded, its record can be overlaid on a geo-spatial map (e.g., using Falcon View). Indeed, visualizing a candidate route specification using Falcon View is an action our flight planner SME's stated they routinely do (cf. Roth: 2003, March). There are multiple reasons why such a graphical visualization of the textual route specification is important, such as:

- It permits the planner to see any anomalous or unnecessary course features (e.g., 'zig zag' routing) that may have carried over from the originally-generated ACFP output.³⁹
- It permits a check on what national boundaries are traversed in the course of the given routing.⁴⁰
- It permits a check on non-geographical elements relevant to the routing constraints and specifications (e.g., FIR boundaries; entry / exit points; exclusion zones).
- When recorded (e.g., printed out), it affords a visualization artifact that can be forwarded to (e.g.) the DIP planner to aid him / her in his parallel planning work.⁴¹

However, there's no direct or realtime support for visualizing the prospective route(s) at the point such a capability would be most useful - i.e., during the planning process itself.

Comments and Analysis:

The current arrangement (visualization after recording a candidate flight plan) has the following effects:

- It splits user attention between two distinct on-screen applications during any repeated cycles of plan - record - visualize - edit actions.
- It doubles the number of applications with which the user must interact in the course of jointly visualizing and manipulating route specifications.
- It delays comprehensive visualization of a route product until that product has been stored and can be graphically overlaid on a map.
- This delay necessarily forces the flight planner to go through one plan / visualize cycle before he / she has the first cue on problems.
- The range of problems apparent only after this first cycle may well include things the planner could not or did not take into account owing to cognitive overload.
- This arrangement therefore heightens the risk of missing, misconstruing, or misapprehending relevant plan elements on the first pass.

³⁹ Cf. Roth (2003, March)

⁴⁰ KA visit to XOCZ, December 2002; Roth (2003, March)

⁴¹ KA visit to XOCZ, December 2002

- This arrangement therefore reduces the probability of generating a comprehensively 'correct' or 'viable' flight plan on the first pass.

These and other factors make the current arrangement one which increases cognitive and procedural burdens on the user, increases the opportunities for errors, increases the minimum time necessary to do the flight planning function, and hence decreases the nominal efficiency of the flight planning activities.

By the middle of our Phase II GAMAT Phase II effort we had begun probing our SME's on the perceived utility of adding a graphical component to the standard flight planning IT suite. The responses we received were uniformly positive toward this idea. As a result, we elected early on to make graphical support for flight planning a key attribute of the WCSS recommendations we would make in Phase II.

Summary

The issues and trends outlined earlier in this chapter illustrate what we came to believe are the primary problems capable of being addressed and ameliorated using WCSS innovations. By late summer 2003 we had come to concentrate on the following features or capabilities as the focal themes for our Phase II WCSS design work:

- Incorporation of real-time graphical visualization in the IT support aids providing the flight planning staff.
- Incorporation of new route manipulation capabilities leveraging this new graphical representation (e.g., via direct manipulation of on-screen elements).
- Renovation of the current and / or next-generation F2 Database (or equivalent) to permit addressing routes at a minimum of two levels of granularity.
- Leveraging the implied imposition of a more structured organizational schema for route data to make maintenance of the flight planners' route specification database both more efficient and more effective.
- Designing flight planning IT aids such that they were of utility to the broader population of TACC users (i.e., not designing solely for the experienced flight planners).
- Making provision for supporting other TACC players (most particularly the mission planners) with a capability for generating notional flight plans without having to request the flight planners do it for them.
- Illustrating the utility of facilitating TACC team situation awareness on constraint and alert conditions affecting mission / flight viability, but not directly and immediately inspectable with current individual tools.

The payoffs from emphasizing these themes in our Phase II WCSS designs were expected to come from new capabilities to:

- make route rationale and constraints more visible;
- facilitate all TACC team members' abilities to understand, evaluate and revise a flight plan;
- afford mission planners more information on options and alternatives;
- allow more timely capture and presentation of information necessary for better situation awareness (SA);
- eliminate current 'blind spots' in the TACC process path;
- enable more proactive response across the organization; and
- reduce mission delays and mission 'no-gos'

Beyond this, we wanted to promote TACC-wide team collaboration as discussed in Chapter 1.3. This meant that any flight planner WCSS innovations we prescribed would have to be framed in the context of overall team requirements and not just those of the flight planners per se.

The specific WCSS designs developed and presented as the outcomes of our GAMAT Phase II effort will be presented in Chapters 1.5 and 1.6.

1.5 Work-Centered Design Concepts to Support TACC Flight Planning-related Collaborative Work

This chapter will introduce the WCSS design concepts generated during the Phase II GAMAT effort which address the issues and themes discussed with respect to TACC collaboration in Chapter 1.3. The chapter will begin with an overview of the focal topics we selected for design intervention generally, and then proceed to a discussion of how we believe our prior WCSS analyses, concepts, and prototypes can be extended to provide a collaborative suite supporting all of TACC. In a subsequent chapter we shall address our more specific Phase II WCSS recommendations deriving from the review of flight planning in Chapter 1.4.

Overview: Two Key Foci for Our Design Prescriptions

The Phase II GAMAT project was comprised of multiple tasks, each of which had its own context and objectives. With regard to the new WCSS design component of the project, there were two primary streams of work:

- *Analyzing TACC operations for collaborative information technology needs and opportunities.* This aspect of the Phase II work was dedicated to assessing the prospects for employing IT to support interpersonal and inter-unit collaboration in TACC's planning and execution functions.
- *Analyzing planning and execution functions toward formulating key WCSS intervention opportunities.* This aspect of the Phase II work was dedicated to assessing the prospects for employing WCSS to better support TACC users in the decision making functions they perform in the course of planning and monitoring missions.

In this and a subsequent chapter we shall review how we pursued these two themes during Phase II. One way of characterizing the primary outcomes of our Phase II work is to distinguish them figuratively, in terms of the manner in which they address their subject matter. One is a 'horizontal' dimension, 'cutting across' TACC units and positions, along which we determined we needed to better organize our WCSS deployment objectives. This 'horizontal' dimension is the one applicable to the collaborative issues discussed in this chapter. The other is a 'vertical' dimension along which we had to prescribe visualization modularity in addressing what we considered to be the single more important representational and visualization deficiency in TACC as a whole. Discussion of this second theme will occur in a subsequent chapter.

The 'Horizontal' Dimension: Cross-Position WCSS Utility

Since the first AFRL/HE WCSS project (HISA - FY99 and FY00), we had given consideration to addressing the entire scope of TACC work and designing IT innovations to support that range of users and functions. More specifically, thought was given to what WCSS suite or toolkit would provide comprehensive support for TACC as a whole. In each of the TACC WCSS projects to date, our AFRL team has ended up focusing (most often at TACC request) on one or another role or function. Accordingly, our emphasis on demonstration prototypes has translated these more narrow foci into WCSS designs crafted to fit one or another position or function. In Phase II we attempted to take a step back and evaluate once again the prospects for an overall suite of WCSS tools encompassing both the WCSS designs already developed (and demonstrated, and in some cases even deployed) as well as those which we foresaw as future opportunities.

As of the end of Phase II, our AFRL team had in effect completed a multi-year examination of the diverse units and positions contributing to the TACC mission and flight planning process path. This had given us a broader perspective from which we could see the wider functional and procedural contexts and ramifications for the WCSS concepts we'd developed up until then. By and large, the result was that we had begun to see the broader (cross-position; cross-unit) applicability of some prototypes we had previously designed with regard to one or another position or function. This in turn meant we needed to stop and take the time to re-evaluate those prototypes in terms of how their features might be generalized across units and positions so as to fit within a coherent TACC WCSS suite (as opposed to the collection of standalone tools our previous efforts had produced).

A Comment on How the WCSS Approach Facilitated Collaborative Utility Assessments

Though one can find some variations in the definitions and characterizations employed to explain work-centered design and work-centered support systems, these are minor. The dominant and central theme in WCD is that user interfaces and tools should be crafted to reflect the form and the flow of specific work activities. With sufficiently cogent and perceptive analysis of these specific work activities, the essential elements of a given work activity are identified and correlated with elements of the work-centered designs (including the composite configuration and interplay for a set of multiple WCSS products).

By focusing on the work itself (its topology, its structure, its flow, and its context) WCD seeks to fit the information technology to what its user does. Other aspects of the work milieu (e.g., role definitions, organizational structures, and especially the affordances and constraints of particular products and implementations) are treated as less critical to the specification of work-centered designs than they are in conventional engineering practices. Granted, these other factors influence the final WCSS outcomes, but they don't uniquely determine what these outcomes should be.

Beginning with the HISA project in 1999, our AFRL team has sought to identify, analyze, and codify the key elements defining TACC's mission planning and sortie execution functions. By concentrating on these more abstract features of the work activities, we have developed WCSS design concepts which reflect the nature of the work accomplished by TACC, and which do so with a degree of generality affording us the ability to disentangle ourselves from transient details of hardware, software, procedural, and even organizational factors.

One advantage of this relatively abstracted approach is that the resultant WCSS concepts are not tightly coupled to the specifics of a given position, support suite, or procedure. Our present objective of assessing WCSS in light of TACC-wide collaboration illustrates the payoff to be had from this approach. Had our previous designs been too closely tailored to the task performance and work requirements of one or another specific position (as implemented by particular persons at a particular time and within a particular organizational state), they would have proven 'brittle' in the sense of requiring major rethinking and renovation to be expanded to serve other positions than the one originally targeted in our WCSS research and development. The WCSS concepts generated to date are reflective of the general work to be done and not the peculiarities of how one or another person or unit does that work.

This means expanding these existing WCSS concepts to support multiple roles across the entire TACC team doesn't require a total rethinking of their purposes or essential design elements. Instead, the primary innovation is to evaluate who else can constructively use those generalized features and capabilities these earlier concepts provided their original target users. In other words, a coherent WCD approach based on a deep and generalized understanding of the overall work (e.g., its objectives, critical elements of information, constraints, limitations, etc.) can be 'robust' in the sense that changing other elements of the work milieu (e.g., specific workers, organizational structures, deployment platforms) does not automatically mean junking the existing WCSS concepts and having to create them all over again.

The primary thrust in expanding our WCSS coverage to support TACC team collaboration is therefore an evaluation of the extent to which particular capabilities should be made available across roles, position, and organizational units. In the next section we shall illustrate such an evaluation in terms of what broader user audience we now see for selected AFRL WCSS products.

Assessing Cross-Position Utility for WCSS Prototypes Created to Date

The procedure used in this re-evaluation was to consider what features or design elements of a given WCSS prototype concept would be useful for positions other than the one(s) which served as the original target audience. Of most importance to this discussion were the results of this re-evaluation with regard to four WCSS prototypes - the Port / MOG Viewer; a summary workstream SA aid; the GAMAT weather tool (WCSS-GWM; WMT); and a mission planning tool. In the tables below we shall review these four concepts in a series of summary tables. Within each table the concept and its original target audience (users; roles) will be cited. Then the primary features of that concept will be enumerated. Finally, a list of potential users (beyond the scope of the original target audience) will be provided to illustrate the extent to which the concept (or a variation thereon) could be propagated beyond its original demonstration context.

The Port Viewer: Visualization of Traffic Throughput at a Given Port

The first successful AFRL WCSS design concept was the Port Viewer (also known as the 'MOG Viewer') developed in 1999 during the HISA project. The Port Viewer was originally designed as one of three canonical 'viewers' (summary displays) reflecting the three canonical subcategories of reference relating to an overall mission. These three subcategories were:

- *Port* - each of the two airfields at the departure and arrival ends of a mission / flight.
- *Package* - the set of tangible or discrete items to be accounted for in planning and executing a mission (e.g., aircraft; crew; documentation; cargo, etc.).
- *Passage (later 'En Route')* - the intervening process by which the mission's Package executed a physical transit from the departure Port to the arrival Port.

During the course of the HISA project, our AFRL team was instructed to focus on the specific problem of *maximum-on-ground (MOG)* - i.e., the condition of having too many aircraft on the ground at a given airfield (relative to that airfield's stated limitations). As a result, two things occurred. First, the Passage and Package viewers were set aside and not developed beyond their original notional sketches. Second, the Port Viewer was designed more specifically to serve as a rapid situation awareness aid for MOG conditions. In various forms, this design concept has been developed and implemented in multiple editions during the intervening years. Its perceived utility has clearly been acknowledged by roles / positions other than the channel mission planners for whom it was first conceived. A summary of the collaborative prospects for the Port Viewer is provided in Table 1.5-1.

Table 1.5-1: Collaborative Prospects for the Port / MOG Viewer Concept

WCSS CONCEPT	ORIGINAL TARGET USERS	SUBSIDIARY BENEFITS AND DESIGN FEATURES	WIDER AUDIENCE (other than original target users)
PORT VIEWER (aka MOG Viewer) HISA Project 1999	Mission Planners	<ul style="list-style-type: none">• Structured view of Port traffic throughput• Alert coding for MOG occurrence	<ul style="list-style-type: none">• Flight planners• Flight managers• Execution staff• Management• Wings / Squadrons• APCC

In many respects, a re-evaluation of the Port Viewer in light of TACC-wide collaboration entails a return to the generality of the original HISA concept - i.e., the notion of a summary overview for port traffic and not just a MOG-specific gadget. Tracking traffic throughput at a given port is something of utility for almost all positions within the TACC process path. As such, a Port Viewer could - with little modification from the currently-deployed prototypes - serve as a common tool for the wider audience cited in Table 1.5-1. Because the visualization requirements are essentially identical across this population of potential users, there is no perceived need to tailor or propagate the Port Viewer concept into a set of related tools. Accordingly, the means for elevating the Port Viewer from a specific aid to a component of an overall TACC collaborative toolkit is to simply propagate a deployable version to a wider audience.

The Mission Status Display: Summary Situation Awareness on the TACC Work Stream

'Mission Status Display' was the first label given to the concept of a summary listing of all active mission 'cases' making their way through TACC from initial planning to final execution. The concept of an ordered list of active 'cases' dates back to the original designs sketched out during the HISA project (1999 - 2000) in relation to channel mission planners. However, the work stream SA display aspects were subordinated to the alerting aspects, for which a prototype was produced in 2000. This concept surfaced again the following year in the IFM project, when once again our analyses of planning activities (in this case involving flight managers) suggested such a summary work stream overview was necessary. Since then, this concept has been commonly referred to as 'the to-do list', connoting its role as the user's window onto the pending and active workstream. During the GAMAT phase I work, a 'Sortie Palette' was developed and demonstrated as the first working software prototype for this concept. The collaborative prospects for this concept are illustrated in Table 1.5-2.

Table 1.5-2 Collaborative Prospects for the Mission Status Overview Display

MISSION STATUS DISPLAY (aka 'To-Do List')	Flight Managers	Summary overview of TACC workstream	Summary overview of TACC workstream
IFM Project 2000 - 2001 (cf. the 'Sortie Palette' feature in the GAMAT GWM-WCSS)		<ul style="list-style-type: none"> • Summary overview of TACC workstream • Ordered listing of active mission 'cases' • Summary mission ID info • Summary alert / status coding for individual missions / cases • Ability to rapidly assess the status of the overall workstream • One-click drilldown to individual mission record(s) 	<ul style="list-style-type: none"> • Mission planners • Flight planners • Execution staff • Management • WX staff • DIP planners • Barrelmasters • APCC • Wings / Squadrons

As Table 1.5-2 illustrates, the concept of a summary workstream overview is of use to just about everyone involved in the TACC mission planning and execution process. Indeed, reference to the workstream comprised of 'cases' (individual missions being processed) is the most general conceivable information requirement for TACC operations. Accordingly, a summary display providing situation awareness over this workstream is the most generally-useful information aid conceivable for TACC. As such, this sort of workstream overview is in effect the 'spine' (most critically informative) for an overall TACC collaborative IT suite.

However, as was the case for the Port Viewer, this mission status listing is sufficiently generic that there is little if any need to tailor or differentiate variants to support different roles or units within TACC. Accordingly, the means for elevating the mission status 'to-do list' from a specific aid to a component of an overall TACC collaborative toolkit is to simply propagate a deployable version to a wider audience.

The GAMAT Weather Tool: Visualization of WX Impacts on Mission and Flights

The WCSS-GWM⁴² weather information visualization tool created and developed under the aegis of our GAMAT ATD has been the object of the longest continuous development and refinement process of all the AFRL WCSS products to date. Though it has had obvious significance in providing single-point meteorological visualization and reference support to TACC personnel, even in prototype form, the WCSS-GWM has perhaps an even greater eventual significance for its more generic features as a work-centered interface.

The most important aspect of this generic significance is related to the fact that the WCSS-GWM is the first WCSS prototype to emphasize geo-spatial visualization (i.e., maps). As a natural phenomenon, weather correlates with geographical location. As a result, visualizing meteorological data is most effectively done through representations correlated with geographical features. However, it is not only the weather which is effectively visualized with respect to geography. Flight routing is similarly correlated with geography, because (e.g.):

- Flight departure and arrival endpoints are indexed with respect to geographically-specified locations (i.e., airfields).
- Flight routes are defined with respect to geographical locations (waypoints; lat / long coordinates, etc.).
- The majority of operationally-delineated routing elements (e.g., exclusion zones; areas of ATC responsibility) are defined with direct or derivative regard to geographical locations (e.g., an area defined by a given radius around a fixed geo-spatial point).
- The primary means for tracking flight progress is through aircrew reports citing geographical location.
- The ancillary diplomatic clearance factors bearing on routing opportunities and limitations are delineated with respect to geographical locations (the national territory being transited).

As a result, the sort of geo-spatial visualization of such clear utility in visualizing weather in the WCSS-GWM recommends itself for visualizing flight routes for planning and execution purposes. In contrast, some of the WX-specific features and design emphases embedded in the WCSS-GWM prototype are of lesser criticality for a flight planner than for, say, a weather squadron staffer. A breakdown of the WCSS-GWM features suitable for the WX shop specifically and the TACC team generically is illustrated in Table 1.5-3.

⁴² WCSS-GWM is an acronym for 'Global Weather Management - Work Centered Support System'. This was the culminating title for this product. At various times and among various people this tool has also been known as: 'Weather Management Tool (WMT)'; 'GAMAT Weather Tool'; and simply 'GAMAT'. For the purposes of this report, we shall attempt to use the final label WCSS-GWM exclusively.

Table 1.5-3: Collaborative Prospects for the GAMAT Weather Tool

WCSS CONCEPT	ORIGINAL TARGET GROUP	SUBSET OF WCSS FEATURES OF PRIMARY RELEVANCE TO THE WX SHOP	SUBSET OF WCSS FEATURES OF WIDER RELEVANCE TO THE TACC TEAM
GWM-WCSS (aka 'GAMAT tool'; 'Weather Mgmt Tool') GAMAT Projects 2001 - 2003	WX Shop	<ul style="list-style-type: none"> • Single point access to diverse WX data streams • Fusion of WX data into a single WX overview 	<ul style="list-style-type: none"> • Execution staff • Flight managers • Execution supervisors • Wings / Squadrons • Flight crews
		<ul style="list-style-type: none"> • Central geo-referenced visualization display • Multi-layered display elements • Ordered set of relevant data / info layer options • Ability to select / mix overlays interactively • Vertical flight profile view 	<ul style="list-style-type: none"> • <i>All the above plus...</i> • Mission planners • Flight planners • Planning supervisors • DIP planners • Barrelmasters • APCC

In this third example we see something different from what our collaborative utility assessment developed with respect to the two preceding examples. In those earlier cases, the WCSS tools were evaluated to be of wider utility in more or less their original / current forms. In the case of the WCSS-GWM, there is a distinction to be drawn between (a) the subset of WCSS-GWM features of primary relevance to the WX shop alone versus (b) the subset of WCSS-GWM features of wider relevance to the TACC team as a whole.

This distinction can be framed with respect to temporality.⁴³ Weather is, of course, a very changeable phenomenon. Weather information - including composite visualizations - have a relatively short period of usability before changes mandate an updated record. This temporal constraint results in detailed WX data being of primary utility to those TACC roles who must deal with flights / missions in the hours just before launch and throughout the execution phase.

⁴³ To be fair, there's more than one context for framing this differentiation. In light of this report's earlier emphasis on temporality in TACC operations, this particular context was judged to be especially pertinent.

Flight routes, on the other hand, are amenable to longer unmodified duration (e.g., from planning weeks in advance through the execution phase). This, combined with the aforementioned primacy of geo-spatial reference in route visualization, suggests that generalization and broader dissemination of the sort of geo-spatial capabilities exemplified by the WCSS-GWM could serve as the basis for route-oriented information aiding. Phrased another way, one can readily see the WCSS-GWM as an example of a general geo-spatial visualization tool whose specific form and functionality are attuned to the particular work of the weather shop. Accordingly, one can just as readily imagine another variant on such a generic visualization tool configured more to fit the requirements of those other TACC roles whose focus is on routes.⁴⁴

The subdivision of WCSS-GWM features in Table 1.5-3 is, therefore, necessary to weed out those features peculiar to the prototype's original target user population and to highlight those features of more general relevance. This doesn't mean the two sets of features are mutually exclusive. Neither does it necessarily imply that weather-oriented features should be strictly segregated from route-oriented features. Weather personnel need to reference routes - for example, in determining which regions should be covered in the current shift's chart update process. Conversely, execution cell personnel need to be able to reference weather conditions - for example, in assessing the feasibility of a proposed alternative route or the viability of a diversion to one or another airfield.

The point is that in the case of the WCSS-GWM, we can discern a basis for generalizing the specific WCSS prototype's key feature (geo-spatial visualization) to serve as the basis for a more generic (and more broadly deployed) work-centered aid. The resultant route-oriented geo-spatial visualization tool (termed the *Flight Visualization Tool - FVT*) will be discussed in more detail later in this report.

The Flight Planning Palette: A Unified Aid for Mission and Flight Planning

During the IFM (Integrated Flight Management) project (2000 - 2001), an AFRL team observed and analyzed the work of the then-new flight manager (FM) position. One of the outcomes of that effort was a concern for diversity of disparate tools an FM had to invoke and manipulate in the course of finalizing a flight plan and assembling the requisite documentation to 'paper the crew'. Our WCSS prescription for this issue was a single unified 'Flight Planning Palette' which provided a single on-screen workspace for generating the route (and other) specifications and for tracking the FM's procedural progress on a given mission. This concept was briefed to the FM's and other TACC staff in spring 2001. At that point, AFRL involvement with the concept stopped. As we later learned, the FM's were sufficiently enthusiastic about the Flight Planning Palette concept to have TACC contractors generate them a working prototype. This prototype has been deployed for FM use under the name 'Sortie Manager'.

⁴⁴ This quite clearly illustrates the fact that our WCSS research efforts, though generally undertaken with respect to broad or generic characterizations or the target work processes, have historically ended up focusing on relatively more narrowly-defined prototypes geared to the specific needs of one or another TACC position or unit. Geo-spatial route visualization was nominated as a possible aid for channel mission planners back in the 1999 HISA project, but it was ruled out as suboptimal for the purposes of planning a 'mission' (a goal-oriented task specification) as contrasted with a 'flight' (a physical movement between departure and arrival ports to accomplish the purposes of an associated mission).

As was the case with the WCSS-GWM earlier, this Sortie Manager tool embodies features which can be subdivided with respect to (a) those which are most pertinent to flight managers (and similar planning personnel) and (b) those which recommend themselves as pertinent to the objectives and tasking of other roles. This is illustrated in Table 1.5-4.

Table 1.5-4: Collaborative Prospects for the Flight Planning Palette

FLIGHT PLANNING PALETTE	Flight Managers	DESIGN FEATURES	DESIGN AUDIENCE
IFM Project 2000 - 2001 Implemented as FM's 'Sortie Manager' tool		<ul style="list-style-type: none"> • Working area for generating flight documentation • Organized to reflect stepwise planning procedure (and progress thereon) 	<ul style="list-style-type: none"> • Flight Planners • Mission Planners
		<ul style="list-style-type: none"> • Fused accessibility to relevant mission data / planning info in a single-point reference asset. • Single-point reference on mission / flight planning process • Single-point drilldown capability to supporting / detailed planning documentation 	<ul style="list-style-type: none"> • <i>All the above plus...</i> • Execution staff • Supervisors (for planning oversight) • Wings / Squadrons • Flight crews • Barrelmasters • APCC

As Table 1.5-4 indicates, the 'working area' aspects of the Sortie Manager are of primary importance to those whose tasking includes generating flight plans and other crew documentation. However, the form and organization of the original Flight Planning Palette concept was also designed to provide a coherent single reference asset for a given mission. In relation to this 'reference' aspect of the WCSS design concept, we can now see a larger audience to whom its utility can be extended. There are a variety of TACC team members who are not directly involved in the final flight planning process, but whose own work could be facilitated (if only under special circumstances) by an ability to call up a structured planning record to see (e.g.) where the planning process stands, what rationale or parameters were included in generating the current plan, and so forth. In other words, this concept (in generic form) can serve not only as an interactive tool for those planning flights, but also a situation awareness aid to allow other TACC team members to monitor or evaluate the planning process or the plan itself.

As was the case in differentiating among features and generalizing the WCSS-GWM, the Flight Planning Palette can be seen as a specific instance of a more general tool. This notion intersects the idea of a more general Flight Visualization Tool because we are now able to see how geo-spatial visualization could constructively support flight (as contrasted with mission) planning. The interrelationship between a generalized planning palette and a generalized flight visualization aid will be discussed in more detail later in this report.

Summary

As discussed earlier in Chapter 1.3, fostering better overall team performance in TACC operations is more properly a matter of promoting better 'coordination' (e.g., uniform situation awareness on the work stream, individual cases, etc.) among specialized team members than a matter of imposing more real-time 'collaboration' (i.e., work practices requiring joint attention and action by multiple TACC team members). The former (coordination focus) sets the stage for, and does not hinder, the latter. The latter, even if successfully implemented, does not guarantee the payoffs expected of the former.

None of our earlier WCSS prototypes are entirely unsuited to deployment as collaborative tools across TACC. Two of the prototypes (the WCSS-GWM and the Flight Planning Palette) incorporate features which are both position-specific as well as generally useful for a broader TACC audience. As it turns out, these two prototypes are also the ones of most general utility (as information summary displays) to the widest number of TACC workers. Ultimately, TACC's primary information products are mission and flight plans. This has a number of implications. First, it means that there needs to be a coherent means for generating and documenting these plans - one which facilitates the planner's (or planners') navigation through the work process and subsidiary tasks. This is the role of the Flight Planning Palette. Second, it means that there needs to be a coherent means for displaying and addressing the actual flight operations conducted with regard to these plans. This role is exemplified by the WCSS-GWM (as extended from its original weather-specific scope to include portrayal of flight information).

As a result, we ended up framing our approach to collaborative WCSS in terms of extending or expanding existing WCSS concepts and prototypes to serve a wider TACC audience. Though such an approach may seem merely 'convenient', it was entirely justified. Our previously role-specific WCSS products were designed with regard to overall TACC operations (and hence the general scope of the whole TACC team) from the beginning. Because AFRL's WCD approach emphasizes the work environment, a properly-executed WCD project should address and reflect collaborative opportunities for any work environment in which 'collaboration' is an essential feature.

As demonstrated earlier, some of our WCSS prototypes need not be re-conceptualized or re-designed to support an audience broader than that for which they were originally intended. The Mission Status Display ('to-do-list') concept, though initially proposed to support mission planners, is generalizable all across the TACC team because it provides situation awareness over the workstream all team members must handle in some way and at some point. The Port / MOG Viewer concept is similarly generalizable, though for a different reason. It was designed to provide specific situation awareness for a particular thing (traffic throughput at a given airfield) which, as an essential feature of the air mobility domain, is relevant to any and all missions (and hence anyone involved in planning or monitoring such missions). As a result, these two WCSS concepts will not be discussed further in this report.

Additional Note: Another WCSS Concept Generated during GAMAT Phase II

An additional note is in order. In the course of the GAMAT Phase II effort we invested considerable time in examining and analyzing the relationship between the flight planning function and the DIP clearance function. The feasibility and availability of DIP clearances was often cited as a primary class of constraints on the flight planning process and the ability to replan flights as circumstances demanded. However, no reference aid was available to the TACC team to provide them with ready, concise, and easily-interpretable information on the DIP status associated with a given mission. In response to these determinations, a WCSS 'viewer' concept for mission DIP data was generated and briefed during the latter stages of our GAMAT Phase II project. However, this concept was not developed into a prototype for a variety of reasons, including:

- Other WCSS topics (most particularly flight visualization) were accorded higher priority.
- The DIP status 'viewer' concept arrived relatively late in the GAMAT Phase II timeframe.
- There were lingering uncertainties about the extent to which the intended functions of this DIP viewer would eventually be covered in features of the oncoming GDSS 2.

As such, this DIP status display (called the DIP Summary Palette) was not included in the earlier review of precedent WCSS prototypes, and it will not be discussed further in the next chapter along with our flight visualization WCSS concepts. Documentation of the DIP Summary Palette is instead provided in a separate Appendix C.

1.6 Work-Centered Design Concepts to Support TACC Flight Planning Work

This chapter will introduce the WCSS design concepts generated during the Phase II GAMAT effort which address the issues and themes discussed with respect to the work-centered review of flight planning in Chapter 1.4. The chapter will begin with an overview of the focal topics we selected for design intervention, then proceed to a discussion of the specific design concepts developed and presented in various meetings during the project's timeframe, culminating in the GAMAT Phase II PMR (February 2004).

In Chapter 1.5 we discussed the manner in which two of our existing WCSS products (the WCSS-GWM and the Flight Planning Palette) could be deconstructed in terms of the distinction between (a) those design features peculiar to the original target audience and (b) those design features of more general utility across a wider population of TACC team members. This latter category is the one we pursued during the GAMAT Phase II effort, in accordance with our mandate to explore TACC collaborative opportunities. As a result, the main WCSS design concepts generated during Phase II relate to generalizing these features (i.e., geo-spatial visualization and discrete interactive planning workspaces). Given our project's Phase II focus on flight planners and the flight planning process, we emphasized these two generalizations in the context of how they intersect with the flight planning domain.

In the remainder of this chapter we shall introduce and discuss the central products of our Phase II design work.⁴⁵ First we shall address integrated geo-spatial route visualization in the form of a proposed *Flight Visualization Tool (FVT)*. Then we shall proceed to address interactive flight planning support in the form of a proposed *Route Editor*. In addition, we will describe how these two WCSS concepts are intended to interoperate as components of a broader TACC collaborative WCSS toolkit.

The 'Vertical' Dimension for WCSS Intervention: Supporting Coherent Flight / Route Visualization for TACC Users

As discussed in the preceding chapter, our work during GAMAT Phase II can be figuratively characterized as focusing analysis along two 'dimensions', the first of which was a 'horizontal' dimension cutting laterally across TACC positions and subunits. The second or 'vertical' dimension concerns the need and prospects for work-centered visualization of routes within TACC. The rationale for our focus on flight visualization during Phase II derives from multiple factors. The most important and compelling such factor was the general lack of graphical support for the flight planners' work activities.⁴⁶ This deficiency can be construed as inducing or facilitating several performance-degrading conditions, including:

- Inability to quickly invoke a summary overview of a flight's designated route except in the form of a detailed and relatively dense text record

⁴⁵ As mentioned in Chapter 1.5, a third WCSS design concept generated during Phase II (the DIP Summary Palette) is addressed in a separate Appendix C.

⁴⁶ There are graphical tools available (most particularly FalconView), but these are secondary or auxiliary resources with respect to the flight planners' core IT support. The use of FalconView appears to have started and propagated mainly among the flight managers rather than the flight planners. This development began after our 2000 - 2001 IFM project (during which we studied the inaugural group of FM's), but was evident at least as early as early 2002 (during GAMAT Phase I).

- Heightened cognitive burden for any user attempting to understand a given flight from the conventional textual documentation
- Heightened cognitive burden involved in attempting to correlate textual flight or route information with other relevant data provided in separate displays (e.g., different windows on the same screen)
- The general difficulties involved in attempting to discern and analyze constraints and problems using textual documentation.
- Heightened risk of performance errors induced by having to address, analyze, and plan flights using text only
- Collaborative difficulties in trying to communicate information or understanding of route / flight conditions using a textual record as the primary or sole shared reference resource
- The general unsuitability of textual displays for providing peers and supervisors effective situation awareness spanning multiple missions (e.g., in the execution phase)
- The persistent and pointed interest shown by planning and execution staff in the graphic capabilities developed in our Phase I project for the weather staff
- Recurrent references made by flight planning and other TACC SME's to their belief that more graphically-oriented visualizations would greatly improve their effectiveness and efficiency in planning and flight monitoring.⁴⁷

As will be seen more clearly in subsequent sections of this report, the need for flight / route visualization led us to develop work-centered representational schemata predicated on multiple layers or levels of reference. In other words, our visualization design work led us to prioritize information composition in relation to a 'vertical' dimension of composition and / or abstraction.

⁴⁷ It is important to emphasize that SME opinions and suggestions are treated as very important information in the context of our work-centered approach. Our knowledge acquisition is conducted under the rubric of a general principle to the effect that no one knows the work better than those who actually perform it. As a result, we made a point to conduct demonstrations, presentations, and interviews to give the SME's a regular update on our views of their work, their problems, and our concepts for helping them. Conversely, we continually solicited SME feedback to obtain opinions, suggestions, and other data to aid us in evaluating and refining our ideas and proposals.

There is another important sense in which this flight visualization work represented interest in a 'vertical' dimension. This sense has to do with the chain of command and the organizational hierarchy within TACC. As indicated in the list of performance-inhibiting issues above, TACC supervisory staff (e.g., seniors) are at a disadvantage in trying to maintain summary situation awareness over multiple missions while relying on text-intensive information displays. One of the reasons we prioritized route visualization in our GAMAT Phase II project was our belief that a coherent graphical route display capability would be of as much (if not more) immediate utility to supervisory staff as to planners themselves. In other words, we were operating with respect to a secondary type of 'verticality' in the context of fostering better collaborative performance within the overall TACC team (cf. Chapters 1.3 and 1.5).

Flight Planning: Key Elements Underlying a WCSS for Flight Planning

The GAMAT Phase II WCSS design work was predicated on a set of criteria which were derived from the information we'd gathered during our multiple KA efforts and the analyses of that information. Generally speaking, these analyses led to three interrelated categories of themes and proposed innovations, culminating in a set of WCSS design criteria, as described in the following subsections.

Specific Functional Enhancements

Our analyses led us to identify key task-related functions which we felt needed to be prioritized as payoffs from the WCSS designs. These functions correlate with one or more of the TACC positions we studied during the two years of the GAMAT project to date and / or prior WCSS projects at TACC. Our set of prioritized functional objectives can be summarized as follows:

Enable Flight Planners to:

- more effectively visualize the route specifications that are their primary work foci
- create, edit, and / or manipulate route specification data in a manner more efficient than is currently the case (i.e., exclusively through text editing)
- reduce the risk of performance errors by addressing routes in terms of graphical representations (as opposed to having to imagine routes based on text descriptions)
- more efficiently capture flight planning knowledge accrued over time
- better maintain their corporate flight planning knowledge base (i.e., the F2 database and / or its evolutionary successor)
- store and evolve this knowledge base in a form more amenable to supporting other TACC team members through effective graphic visualization

Enable Mission Planners to:

- avail themselves of more information on route options and alternatives
- access this routing information in a form less demanding of expert interpolation and interpretation than currently-available documentation (i.e., the textual route specifications currently in use)
- generate notional flight plans on their own, without having to rely on the flight planners exclusively
- use their self-generated flight plans to get a head start on the DIP clearance planning without having to wait on flight planner intervention

Enable the entire TACC team to:

- efficiently retrieve and view the planned routing associated with a given mission
- efficiently retrieve and view the state of DIP clearances associated with a given mission
- more easily understand the temporal constraints of DIP clearances currently in place for a given mission

General Operational Requirements

More generally, we set out to achieve certain broad objectives relating to overall TACC operations (as contrasted with individual roles, tasks, and functions). Our set of prioritized operational objectives can be summarized as follows:

- Design WCSS visualization / display products of sufficient generality to support a broader audience within the TACC team.
- Design such visualization products so as to facilitate rapid and effective situation awareness (SA) with respect to both (a) individual missions and (b) a set of missions.
- Allow timely capture and presentation of facts and changes to provide better situation awareness.
- Make rationale and constraints associated with a given route more 'visible' (both literally and figuratively) and hence more understandable.
- Provide the capability for visualizing flights in a manner more representative of those flights' operational character (i.e., graphically and geo-referenced).

Technical Innovations

Given the above-cited functional and operational objectives, we determined what particular technical innovations would be needed to devise WCSS. Our set of target technical innovations can be summarized as follows:

- Fusion of route info with other key data (e.g., geography, weather) in a unified visualization scheme presented to TACC team members on their respective displays.
- Ability to address and manipulate route data at different levels of granularity, ranging from an entire route down to an arbitrary section of that route.
- A coherent route representation schema affording an orderly protocol for addressing both entire routes and their constituent route elements
- Coordination (or better yet - integration) of these visualization innovations with other WCSS capabilities for generating, editing, and / or manipulating route specifications.
- An improved route data repository (e.g., a next-generation F2 database) reflecting the route representation protocols / schemata cited in the previous points

Summary: Our WCD Working Criteria

With respect to direct support for flight planning, the primary WCSS design criteria can be summarized as follows:

- A flight planning WCSS must provide a *coherent visualization platform* for the common geo-context⁴⁸ and those constraint cues associated / correlated with this geo-context.
- To promote coherence in addressing routes, a flight planning WCSS must provide for '*multi-level*' *route referentiality* allowing users to address route specifications at different levels of granularity.
- To address team members' diverse needs, a flight planning WCSS must provide:
 - '*dual-mode*' (*graphical / textual*) *route display and manipulation*
 - *automatic correlation / updating of one versus the other (mode)*

⁴⁸ The term 'geo-context' is used herein to denote the set of geo-spatial elements, dimensions, etc., necessary to portray relevant information in terms of geographical or spatial correlates.

In the following subsections these criteria will be discussed in more detail and in the order in which they were cited above. For each of these criteria, we shall provide a deeper discussion of each criterion's criticality and ramifications, and then present our proposed solution to meeting them in the context of the GAMAT Phase II work.⁴⁹

Providing a Coherent Visualization Platform for Geo-Context

As stated above, the primary referential (and hence visualization) context for evaluating flights and the constraints affecting them is a geo-spatial one. A flight is a procedure which results in the movement of a set of materiel (i.e., an aircraft, its crew, its cargo, etc.) from a geo-spatially delineated point of departure to an intended point of arrival.⁵⁰ Certainly, there are elements of the flight that can be addressed in terms other than the geo-spatial (e.g., fuel burn rates; elapsed times; incidental weather parameters such as 'headwind'). However, it is the geo-spatial context which provides the referential background against which the largest proportion of the pertinent aspects of a flight (during and with respect to its execution phase) can be portrayed.

The candidates for such 'pertinent aspects' to be superimposed atop a geo-spatial background are numerous. There are a variety of data types of possible relevance to be fused in a route visualization, and there are multiple overlays / layers within each type. This introduces the potential for problematical visual complexity, given the range and number of phenomena which impinge on the viability and success of a single given flight. A sufficient flight visualization platform will have to make allowance for the full range of these numerous relevant elements. An efficient flight visualization platform will have to be capable of readily portraying these elements and allowing users to manipulate them to fit the purpose at hand. An effective flight visualization platform will have to accomplish these objectives in a fashion which allows the user to constructively address his / work task without getting caught up in the mechanics of the interface itself.

This does not, however, mean that everything should be portrayed at once. On the one hand, there are many different roles / positions within TACC, and each one of them has his / her own general and incidental needs with respect to which elements must be inspected at any given time. On the other hand, you never know what's going to be relevant to a given person for a given task. This means that a usable flight visualization platform needs to provide for flexibility in assembling an instance of a display from all the available data elements.

In other words, we need to design and implement our flight planning WCSS central visualization component(s) such that:

- Users are offered all categories of overlay / layer data.

⁴⁹ It should be pointed out that the themes and criteria discussed here do not terminate or become obsolete with the close of the GAMAT Phase II project. As has been the case with our other TACC WCSS projects, these results will be carried forward into FY04 and beyond under the aegis of the WIDE program.

⁵⁰ To use the original WCSS nomenclature from the HISA project, this unit set of materiel is the 'package', the points of arrival / departure are the 'ports', and the multi-faceted object of reference for the procedure is the 'passage / en route'.

- Users have the ability to mix and match which overlays they want on-screen at a given time.
- Users have the ability to organize and manipulate the overlays / layers they currently employ.

Using Multi-Level Route Referentiality to Impose Visual Coherence

To implement an effective flight visualization platform, we need to construct and apply a coherent route element reference framework meeting two general criteria:

- The framework must address 'composition' interrelating the most atomic route constituents up through composite elements (e.g., whole routes).
- The framework must be 'complete' enough to provide a context for describing and outlining the necessary routing specifications.

It is tempting to oversimplify the concept of 'route' by considering it 'that which connects point A and point B.' In practice, however, the routes traversed by AMC aircraft are neither planned nor executed as such simple A-to-B progressions. There are a variety of things which 'punctuate' the overall route into smaller chunks that can be addressed in and of themselves (e.g., waypoints; organized tracks; entry and exit points; and the like).

Even upon cursory inspection, one sees that routes are composite entities made up of a variety of components, and that there's an implied composition hierarchy pertaining to these routes. At the foundation of this implied composition hierarchy, there's the 'atomic' element of a geo-referenced point (e.g., a waypoint defined as a lat / long specification). The 'top-level' element is of course the entire route from departure to destination (i.e., port-to-port). This much is pretty straightforward.

This initial binary distinction between 'points' and 'routes' was the basis for the 'double level visualization' concept briefed to AMC customers and SME's beginning in late summer 2003. This concept was introduced to illustrate our proposal that a more effective flight visualization interface would permit users to address routes in more than one way. However, a closer examination of the taxonomic and terminological bases for everyday practice brought to light a considerably higher degree of referential complexity than this cursory distinction would imply.

Probing and Analyzing Recognized Route Element Nomenclature

A survey of relevant aeronautical terminology was conducted in 2003 as a means for evaluating the prospects for generating the sort of coherent referential framework we sought. This survey was done using the FAA's CATS database - arguably the single most authoritative reference point for aeronautical practice. The survey was done by running multiple searches against the CATS database, each search based on a selected keyword.⁵¹

Each of these searches produced large sets of entries from the CATS database, and many of these entries turned up in multiple of the searches. The search results were collated and compiled with redundant entries eliminated. Some other entries were eliminated on the basis of non-relevance to specifying or describing flight routes.⁵² An illustrative sample subset of the compiled listing is provided in Appendix A.

In the middle ground between these atomic and overall levels of reference there is a confusing array of candidate elements, not all of which dovetail neatly one to another. There's a variety of terminology employed for route elements in this middle ground. Some of this terminology is peculiar to one or another organization (e.g., AMC, FAA). Some of this terminology applies to only one or another phase of the flight being executed (e.g., approach legs). It's not clear that this nomenclature sorts itself out into neat 'stacking categories' which we could readily leverage to construct a coherent taxonomy to be reflected in our flight visualization WCSS.

Categorizing Existing Route Element Terminology

An analysis of the terminology culled from the FAA resources yielded two primary criteria for discriminating among terms and constructs:

- *Spatial / Geometric Scope.* The concepts / terms can be sorted with respect to the geometric dimensionality of that which they denote (e.g., 'points', 'lines', 'areas', and 'spaces').
- *Natural / Artificial / Functional Context.* A second criterion that can be applied has to do with whether the construct / term denote something apparent in the 'natural world' (e.g., shorelines) versus something abstract projected onto the natural world (e.g., political boundaries; navigational fixes) versus something which is peculiar to a flight path rather than the 'world' it traverses (e.g., 'final approach').

⁵¹ Examples of the keywords used include: *airway, route, corridor, segment, region, waypoint, track, path, flyway, sector, FIR, airspace, area, and zone.*

⁵² In other words, some 'hits' involved terms which made allusion to route components, but were not themselves concepts for such components.

No other taxonomic criteria were found which met the critical requirements of (a) correlating terminology onto a scheme of referential relevance to either the work and / or the elements of user interface design; and (b) being of sufficient generality to encompass the range of terminology obtained during the search.

With regard to the first sorting criterion, Table 1.6-1 illustrates a correlation for a summary set of terms culled from the CATS database and the four spatial / geometric categories listed above. A brief working description is given for each of the four categories portrayed, and a representative set of example terms is provided. The set of examples is 'representative' because multiple entries redundant with respect to a given subclass (e.g., 'zones', 'fixes') are listed under the subclass identity alone.

The spatial / geometric 'plot' outlined in Table 1.6-1 is of particular interest in WCSS analysis and design, because 'geometry' is a key component in visualization design, and appropriately effective visualization is a key goal of work-centered design. As it turned out, this spatial sorting provided a 'cleaner' sort than other candidates, in the sense that it addressed the most terms in the most consistent and coherent fashion.

Table 1.6-1: Route Element Terminology Correlated with Spatial / Geometric Categories

GENERAL FORM	DESCRIPTION	EXAMPLES	EXAMPLES
POINT	Any element capable of being specified with respect to a single locus in a coordinate space (e.g., lat / long).	<ul style="list-style-type: none"> • Lat / Long • Fix • Reporting point • Significant point • Vertex 	<ul style="list-style-type: none"> • Waypoint • Intersection • Approach point • Transition point
LINE	Any element construed as a line or linear progression connecting at least two end points.	<ul style="list-style-type: none"> • Path • Route • Centerline for corridor • Final approach 	<ul style="list-style-type: none"> • Track • Flyway • Segment • Course
AREA	Any element delineated in terms of spatial extent in each of two dimensions.	<ul style="list-style-type: none"> • Area • Airport • Airway • Sector • Stopway 	<ul style="list-style-type: none"> • Zone • Aerodrome • Corridor • Clearway
SPACE	Any element delineated in terms of spatial extent in three dimensions.	<ul style="list-style-type: none"> • Airspace • Control sector • FIR • Track structure • Protected airspace • Surface area 	<ul style="list-style-type: none"> • Control area • Danger area • Airway structure • Prohibited area • Restricted area

Still, another type of categorization recommends itself as at least a secondary basis for sorting out route nomenclature. This one was based on the character of the element in terms of two interwoven features. The first of these features relates to whether the element is (a) 'natural' (i.e., the element is, or is deterministically correlated with, a natural feature of the geo-space) or (b) 'artificial' (i.e., the element is delineated with regard to an abstract or otherwise ascribed reference set). This 'artificial' case is further differentiable into two subclasses. The first consists of those artificial elements correlated with geo-spatial abstractions (i.e., those abstractions which can be correlated with geo-spatial features). The second consists of those artificial elements correlated with features delineated in terms of flight parameters or functional bases (e.g., operationally-delineated zones; radius of feasible flight given fuel load).

This second categorization scheme is illustrated in Table 1.6-2. It turns out to be not as comprehensive at sorting the recognized elements as the geometric one illustrated above. Neither does it uniquely partition the set of recognized elements as cleanly as the geometric one. Still, this scheme lends itself to differentiating those elements directly projectable onto a background geographical map from others whose projections rely on other (perhaps arbitrary) criteria.

Table 1.6-2: Route Element Terminology Plotted with Regard to Type of Reference

GENERAL FORM	DESCRIPTION	EXAMPLES	EXAMPLES
NATURAL (Geo-spatial)	Any element explicitly denoting a natural geo-spatial feature or denoting something uniquely correlated with a natural geo-spatial feature	<ul style="list-style-type: none"> • Lat / Long • Fix • Reporting point • Track • Aerodrome • Airport 	<ul style="list-style-type: none"> • Runway • Touchdown zone • Waypoint • Intersection • Approach point • Clearway • Flight Path (as a track)
ARTIFICIAL (Geo-spatial)	Any element which denotes an abstract 'overlay' onto the natural geo-spatial map, but which has no unique correlation with observable natural forms / locations / items.	<ul style="list-style-type: none"> • Vertex • Airspace • Path • Geographic Area of Concern • Air Defense Identification Zone (ADIZ) 	<ul style="list-style-type: none"> • Final approach • Advisory Area • Flyway • Segment • Airway • Significant point • Direct route segments • FIR • Flight Plan Area
ARTIFICIAL (Flight-space)	Any element which denotes an abstract referent that primarily correlates with something (e.g.) functionally or procedurally delineated with regard to a flight / mission and not to the geo-spatial context.	<ul style="list-style-type: none"> • Composite Route System • Control sector • Course • Route • Terminal Area • Sector • Stopway • Touchdown 	<ul style="list-style-type: none"> • Zone • Transition • Transition point • Corridor • Clearway • Flight Path (as a course) • Landing Area • Missed Approach Point

Neither of these sample breakdowns is perfect. Both, however, provide clues for the characteristics best suited for delineating a schema for coherent route visualization. The geometric breakdown illustrates that it is feasible to organize the pertinent terms so as to reflect a composition / decomposition hierarchy. This is an important feature for aiding users in navigating among and manipulating potentially very complex display options and data presentations. The natural versus artificial breakdown is sufficiently comprehensive to suggest that there are useful distinctions to be drawn with respect to category types (as contrasted with representational form as was the case with the geometric approach).

In summary, the geometric breakdown provides evidence that a reasonably coherent schema can be specified for canonical reference items in addressing routes. The second breakdown, in conjunction with other clues obtained from our Phase II knowledge acquisition efforts, provides evidence for the particular visualization layers to be offered a user in a route display. Neither of the above-cited breakdowns is complete enough to use as a design feature 'as is'.

These two sets of clues correspond to two distinct schemas which must be generated in the course of designing a WCSS solution for visualizing routes and providing TACC staff with the sort of multi-level referentiality our team proposed in Phase II. The first is a multi-level schema for organizing the canonical components of a route element nomenclature. This will give a general basis for coherently addressing routes at all levels of granularity and hence the basis for devising interface specifications. The second is an organizational schema for the classes of display layers to be provided in a route visualization WCSS. This schema incorporates the basic route elements outlined in the first schema as the implementation details for how to portray route information along with other data relevant to decisions on what route is or should be specified for a given mission or set of missions.

In the course of our Phase II GAMAT project initial versions of these two schemata were developed. In the following subsections we shall review these draft schemata in more detail. Later we shall review the proposed interface designs within which these schemata will be leveraged and employed.

A Multi-Level Schema for Route Elements

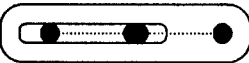

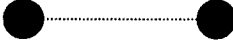
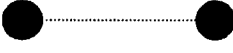
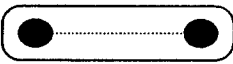

The first task is to lay out the abstract schema covering those general route elements we shall acknowledge in our subsequent WCSS designs and their interrelationships. This schema will determine the types of elements and their correlation within whatever display layer or layers our flight visualization WCSS designs assigns them. The set of layers within which they will appear will be the subject of the next subsection.

As discussed in the previous section, there's an implied composition hierarchy pertaining to routes. In simplest form, this composition hierarchy can be sketched in terms of two extremes:

- The 'atomic' route element is a geo-referenced point (e.g., a waypoint defined as a lat / long specification).
- The 'top-level' element is the entire route from departure to destination (i.e., port-to-port).

This simplistic binary distinction does not capture the obvious intermediate level(s) of reference at which (e.g.) flight planners address and / or manipulate route specifications. Intermediate items (such as arbitrary sections of an overall route) are commonly addressed, analyzed, and modified during the planning process.⁵³ Some examples of such intermediate route components (e.g. North Atlantic Tracks) are discrete units with assigned identifying labels. To account for the atomic and top-level extremes as well as intermediate subsets, the schema outlined in Table 1.6-3 was developed.

Table 1.6-3: A Schema for Logical Route Elements

ELEMENT	SYMBOL	DESCRIPTION
ROUTE		<ul style="list-style-type: none"> • A named / labeled segment set • In simplest form, identical to a named segment. • In complex form, an arbitrary assemblage of named and/or unnamed segments
SEGMENT SET		<ul style="list-style-type: none"> • Any contiguous set of segments comprising a continuous path specification • May consist of any combination of names and / or unnamed segments
SEGMENT		<ul style="list-style-type: none"> • Two points and the implied line connecting them. • The minimal depiction of a route or a portion of a route
• Unnamed Segment		<ul style="list-style-type: none"> • The unnamed segment set is the default case.
• Named Segment		<ul style="list-style-type: none"> • A segment which is discretely addressable using a label or tag • The minimal element necessary to describe an addressable route
POINT		<ul style="list-style-type: none"> • Default: Lat / Long • Alternate: Named geo-location

The schema presented in Table 1.6-3 includes the atomic and composite extremes discussed earlier. The smallest element of reference is a geo-referenced point. The default is presumed to be a geographical point specified in terms of lat / long coordinates. This includes any point capable of being translated into such a lat / long specification. The highest-level element is a route in its entirety (i.e., end-to-end). In between these two levels of reference the schema introduces two additional levels of reference and associated constructs:

⁵³ Indeed, it was with reference to such intermediate 'segments' that flight planners and other TACC personnel suggested there's a need for modular coherent route manipulation as a way to facilitate route specification construction and modification with less effort and cognitive burden compared to the current textual procedure.

- *Segment.* In the context of our route element schema, a 'segment' is any pair of points and the implied line connecting them.⁵⁴ The specification for a segment should include a pair of point specifications (e.g., lat / long or equivalent specifiers). The presumptive connecting line (or path) is an artifact specified by its end points. In actual TACC practice, however, there are 'segments' which are addressable in terms of a label or tag (e.g., North Atlantic Tracks). For this reason, the schema makes provision for 'unnamed' (generic) segments and 'named' (labeled) ones. Named segments are graphically distinguished by an enclosing border.
- *Segment Set.* A 'segment set' is any contiguous series of segments specifying a continuous path or track. A segment set can consist of any combination of unnamed and / or named segments. A segment set can be of arbitrary length. The graphical representation of a segment set preserves the visual distinctions made between named and unnamed segments, thus cueing the user as to which is which.

In this schema, a 'route' is characterized as a named segment set. A 'complete sortie route' would then be a particular instance in which the terminal points at each end correspond (a) to airfields and (b) to those particular airfields designated as the departure and arrival extrema for the given sortie.

This definition leads to a fairly obvious question. One might well ask if there should be a 'named segment set' which is something less than a 'complete route'. Owing to the flexibility with which the elements can be combined, such an intervening candidate element is considered unnecessary. Should there be generated a discrete segment set amenable to subsequent re-use, it should be capable of being assigned a label and 'merged' into a named segment set available for future reference. This presumptive capability essentially negates the criticality of introducing a 'named segment set' and further complicating the schema.⁵⁵

A Multi-Layer Schema for Route Visualization

The second task is to lay out the schema specifying the canonical set of display layers needed to comprise a useful route visualization WCSS and the criteria for their default ordering. In the WCSS-GWM, a number of candidate data layers were made available for WX staffers' selection, inclusion, and relative ordering. Originally, these layers were uniformly representative of meteorological phenomena or data. In addition to these weather layers, additional graphical strata were added. One such stratum contained geo-referenced artifacts representing areas of concern (e.g., alert areas; exclusion zones) projected onto the basic geographical context. Another such stratum depicted routes to allow WX staffers to evaluate where current and / or prospective missions might be.

⁵⁴ This corresponds to the way the term 'segment' is used in (e.g.) FAA nomenclature.

⁵⁵ This is not to say that the notion of a 'named segment set' is ruled out. The schema has been defined to permit essentially unlimited modularity of reference and flexibility of composition. As initially defined here, the schema can be seen as imposing a 4-level (point-segment-segment set-route) organization. Changing this to a 5-level organization through insertion of a named segment set class is a straightforward extension that can be readily done should it subsequently be decided such a move would be useful.

By and large, the WCSS-GWM provided multiple types of representations as layers, but didn't subdivide these layers into subsidiary classes (e.g., a class of WX layers versus a class of route layers). The general flight visualization capabilities we are discussing here will necessitate allowance for a potentially much larger population of available data, and hence a larger set of available layers to be mixed and matched on-screen. For the sake of consistency and coherence in design, we need to generate a schema for categorizing candidate layers in terms of logical classes. This schema must include a tractable number of categories within which all prospective display layer types can be reasonably subsumed. Given the diversity of data already demonstrated to be useful (e.g., in our GAMAT project) considerable thought had to be invested in negotiating the trade offs between minimal number of categories and potentially large numbers of data types. As of the close of our Phase II effort, the draft layer categorization schema had evolved into the 5-level layout illustrated in Table 1.6-4.

Table 1.6-4: A Schema for Route Visualization Layers

Layer Class	Description	Examples
ROUTE LAYER	Flight routing display elements.	<ul style="list-style-type: none"> The route display elements defined in our earlier schema
WX LAYER	Meteorological display elements (both literal and abstracted weather data).	<ul style="list-style-type: none"> Any of the WX data components currently displayed in the GWM-WCSS WX-specific watch areas
OPS-ARTIFACTS (ops-related 'fictions')	Artificial / synthetic geo-referenced elements specific to TACC / USAF ops	<ul style="list-style-type: none"> Theater delimitations No-fly zones AOR's
GEO-ARTIFACTS (geo-related 'fictions')	Artificial / synthetic geo-referenced elements NOT specific to TACC / USAF ops	<ul style="list-style-type: none"> Geopolitical areas Territorial zones FIR boundaries
GEO-BACKGROUND (basic spatial context)	Fundamental geographic elements correlating with physical features of the earth.	<ul style="list-style-type: none"> Specific geo-points Land / sea / physical features

Table 1.6-4 illustrates the five canonical layer classes in play as of the end of our Phase II project. These classes are ordered from top to bottom in the table to reflect their presumptive or default on-screen ordering. The topmost layer class is presumptively 'foreground', and the bottommost layer class is presumptively 'background'. The specific order illustrated in Table 1.6-4 was developed on the basis of multiple factors, including:

- *Temporal persistence.* Those layers representing elements that are relatively transient or mutable are positioned toward the 'foreground', while those that are relatively fixed or persistent are positioned toward the 'background'.
- *Manipulability.* The reason the Route Layer is presumptively 'foreground' is that a route (as an object of reference) is the primary type of representation subject to manipulation by a user.⁵⁶

⁵⁶ This claim is made in the specific context of a tool for flight / route visualization.

Conversely, the Geo-Background Layer is presumptively 'background' because the geo-spatial or physical context is the one least amenable to manipulation.

- *Distinguishing 'Natural' versus 'Artificial' Elements of Reference.* All the route elements identified in the CATS database search are explicitly geo-referenced, or readily capable of being correlated with geo-spatial coordinates. However, there's an important distinction that this geographical commonality obscures. Some of the route elements are clearly artifacts defined with respect to (e.g., USAF) operations and are best considered as abstractions projected onto the geo-space. In addition to being defined operationally, these abstractions are often of the most immediate operational consequence. To reflect this distinction, ops-specific and geo-specific artifacts were separated into two different classes.⁵⁷ Of the two, ops-specific constructs were considered more likely to be 'foreground' (cf. above-cited factors) than the geo-specific constructs.

Dual-Mode Route Display and Automatic Inter-Modal Correlation

It's clear that geo-spatial visualization would aid the various roles in addressing routes. It's also clear that textual details (e.g., waypoints; entry / exit times) are material to defining feasibly executable routes. It's clear from our KA results in Phase II and previous years that TACC staffers may use both of these representational and reference modes to address and engage their work subject matter.

As a result, it is a straightforward conclusion that our WCSS designs for general flight / route visualization aiding will have to reflect the following:

- *The WCSS design concepts must provide for display of both graphical and textual data.* Graphic representations hold the greater promise for affording TACC users overview information that is easy to grasp (in general terms) and quick to absorb. On the other hand, textual data is the better choice for supplying users with details (e.g., lat / long specifications) for elements displayed graphically.
- *The graphic and textual displays must be linked / correlated as to what they're showing the user at any given moment.* In other words, the WCSS route visualization display(s) must be capable of presenting the user with corresponding and correlated data of both types upon initial invocation. For example, the WCSS should provide on-screen display of both the graphical view on a given route and the text containing its details. Selecting a discrete route on the graphical display should (e.g.) automatically populate the associated text display with the data for that selection. Conversely, bringing up the text summary on a particular mission / flight could automatically highlight that same item on the graphical map display. In this way we can design the WCSS such that the user's focus is highlighted across data / display modalities.⁵⁸

⁵⁷ Another reason for segregating out the operationally-delineated elements is that these are subject to being relevant and / or persistent based on the purpose at hand. One can easily conceive of a situation in which a planner or execution staffer might want to look at the geo-space in terms of distinct operational parameters (e.g., ATC versus USAF versus naval 'zones of concern').

⁵⁸ The objective, of course, is to reduce cognitive burdens imposed when a user must spend additional time and effort locating data under one modality which is associated with an object of reference addressed within the other modality. For example, let's say there are two display elements affording the user graphical and textual information on a set of missions

- *The data within these displays must be cross-correlated so that updating / changing one automatically updates the other.* For the sake of clarity, we must point out that the correlation / correspondence mandated in the foregoing point (about initial invocation) must carry forward as dynamic changes occur in the underlying data or in the state of the display as induced by the user (e.g., when the user manipulates an on-screen graphic element to simulate a route change). In other words, we mean to imply an intent to implement on-screen cross-correlation for active manipulations of data (beyond 'passive' viewing of the data). This cross-correlation will permit agents to update either of the displays (graphical or textual) in response to changes made on the other. This dynamic coordination will permit planners to see and evaluate the effects of changes made in either mode.
- *The allocation of graphic and textual data within and / or among on-screen WCSS displays must be consistent and understandable.* There are multiple ways in which graphical and textual data can be associated on-screen. One approach is to provide (e.g.) graphical maps and give the user the ability to rapidly invoke the other data type (e.g., text details about a point on the map) as he / she sees fit. Another approach is to provide multiple on-screen display elements, one for each of the data types (e.g., a map palette with a separate structured textual palette displaying detailed data for a graphical object selected on the map). Whether we choose one or more tactics in our WCSS designs, we must be consistent in our overall approach.

The Flight Visualization Tool (FVT): Introduction

The central component of our redesigned WCSS toolkit is a geo-spatial visualization aid allowing TACC team members to efficiently and effectively review route information in a manner closely reflective of the actual flight being (or to be) executed. Broadly speaking, this aid will incorporate many of the features first prototyped and demonstrated with regard to weather functions during Phase I and Phase II of the GAMAT project. Like the WCSS-GWM, this aid will highlight a central graphic map display. Like the WCSS-GWM, this aid will provide its users with a comprehensive set of overlay layers which can be mixed and matched to suit that user's particular needs. The label we created for this general visualization aid is the *Flight Visualization Tool (FVT)*.

Although both WCSS concepts employ a central geo-spatial display, the FVT differs substantially from the earlier WCSS-GWM. The most important such difference concerns the degree to which each of these WCSS concepts is intended to serve as either a standalone application or an integral component of a larger suite. The WCSS-GWM was designed to be a tool primarily aimed at visualizing weather phenomena. The function of generating new work products was a relatively limited one in the case of weather, consisting mainly of generating weather charts. These potential output products were mainly framed in the same manner as the visualization itself (i.e., geo-referenced graphics).

(designated missions A through J). If the user selects mission F in either of the display modalities, we can minimize his / her cognitive burden by automatically highlighting the representation of mission F under the other modality.

These characteristics don't carry over to the FVT. Mission and flight planners must employ and produce a wider range of information artifacts, most of which are not of the same (graphical / geo-referenced) species as the visualization features we propose for the FVT. For the most part, these are textual artifacts, and their processing is a matter of text editing. As such, an FVT is less amenable to direct incorporation and / or generation of flight planning work products (e.g., a textual route specification document) than was the case for the WCSS-GWM and (e.g.) weather charts. As a result, the FVT is intended to serve as one among many WCSS tools within an overall suite - a deployment and use context considerably different than was the case for the WCSS-GWM.

This means that the FVT has to make provision for coordination with other 'outboard' tools. Some of these outboard aids may be read-only information retrieval mechanisms (e.g., a Form 59 display). Others will necessarily be interactive palettes within which textual flight specifications are both displayed and / or edited. This in turn means that the FVT design has to make provision for:

- Easy invocation of relevant outboard information displays and tools
- Coordination of on-screen display characteristics (e.g., foregrounding) relative to these outboard aids
- Sharing (e.g., mirroring) of specific data between the central FVT and the outboard aids
- Coordination of data states (e.g., cross-correlated updates) between the FVT and the outboard aids
- An ability to disengage such cross-correlation should the user desire to explore a 'what-if' scenario (e.g., on the FVT display) without automatically recording the states of this exploration (e.g., until a final decision is made)

Allowing for these capabilities will require that the FVT include design features above and beyond those represented by the earlier WCSS-GWM. There must be controls allowing the invocation of outboard aids. There must also be mechanisms for cueing the user as to which aids are available or active at any given time. Provision has to be made on the FVT itself for displaying any data shared with a given outboard aid.

The intended generality of the FVT as a visualization tool means that it will display a variety of selectable elements on which a user should be capable of 'drilling down'. The appropriate or feasible outboard information aids and tools will need to be made context-specific with regard to which type of on-screen element is being prioritized. For example, invocation of a Form 59 is a reasonable action when one is focusing on a given mission being displayed on the central map visualization. However, a Form 59 is a nonsensical option to offer someone in the context of a selected airfield or national entity. Such nuanced contextual distinctions add complexity to the design requirements for such a general purpose tool as the FVT is proposed to be.

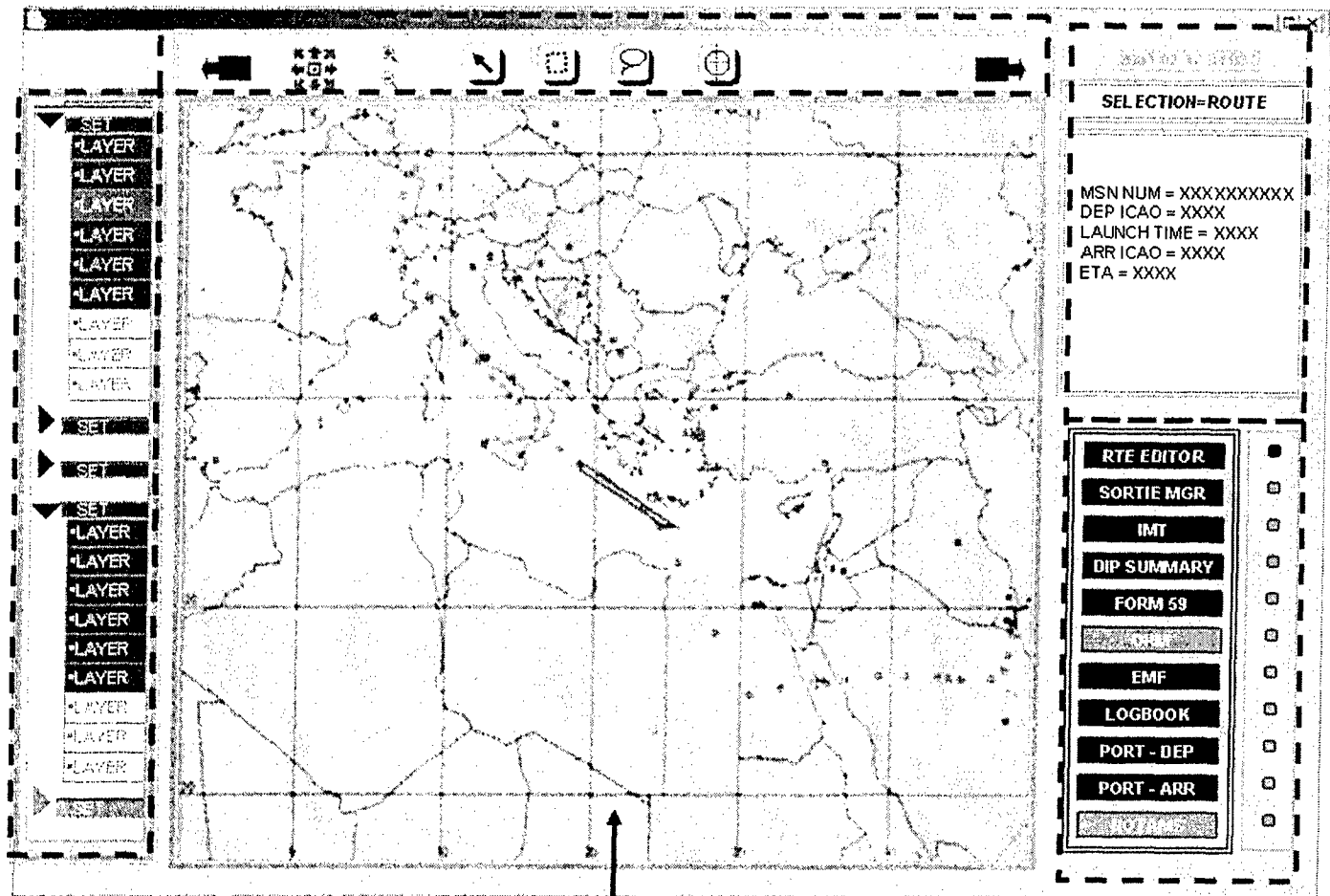
Another way in which the FVT differs from the WCSS-GWM lies in the scope and number of potential data layers for which its design must provide. As a tool focused on weather phenomena, the WCSS-GWM needed to encompass a range of overlay data categories circumscribed by available weather data assets. During the course of the GAMAT projects, this basic meteorological repertoire was augmented with route depictions. As a more generic display tool, the FVT must be capable of handling a potentially greater number of such overlays. This means that visual complexity will almost certainly be an even bigger issue with the FVT as it was with the WCSS-GWM. It also means that layer management options and controls need to be streamlined in the FVT to avoid overloading the user's ability to understand and employ them.

The Flight Visualization Tool (FVT) Concept

During the last months of the GAMAT Phase II project a conceptual prototype for a Flight Visualization Tool (FVT) was developed and briefed. This initial concept was generated as a variation on the WCSS-GWM prototype design. The main feature carried forward from the WCSS-GWM is a central geo-referenced display with flexible capabilities for composing the optimal multi-layered visualization for the work at hand. In addition, the longstanding WCSS principles of 'centralized visualization' and 'peripheral control' guided the FVT design. In the following subsections we shall introduce and discuss the elements of this FVT concept. The general form of this initial FVT concept is illustrated in Figure 1.6-1.

Geo-visualization Controls/Tools

Auxiliary Information Display



Layer
Displays/
Controls

Geo-visualization Display

Outboard
Palette
Selector

Figure 1.6-1: Flight Visualization Tool (FVT) Concept

As shown in Figure 1.6-1, the FVT design concept is arranged in accordance with the WCD principles of 'central visualization / peripheral control'. In the center is the graphic representation of a geographical space, atop which are arranged user-selectable 'layers' for a variety of features and factors. Above this central visualization panel are the basic controls and tools for manipulating the general geo-spatial display content. To the left of the central display element are the layer controls and tools. These are grouped together to provide composite all-in-one cueing and control over the layers a given user has (and / or may have) superimposed on the geo-spatial background in the central display. To the right of the central display element are two new elements. The upper is a composite display element providing auxiliary textual information to the user. The lower is a composite set of selection options through which the user may select and invoke additional ('outboard') WCSS tools. In the following subsections we shall discuss these subsidiary components of the FVT design concept in more detail.

Geo-Visualization Display

The central visualization is a geographical map upon which route, weather, and/or other relevant data elements may be layered. With regard to the GAMAT Phase II emphasis on flight planning, the most important such elements are those that relate to routes. The FVT concept is intended to permit modular overlays of routes, sets of routes, and subsidiary elements of an individual route (as needed), affording the user(s) the ability to correlate and evaluate one or more routes with respect to the geo-spatial context. Grounding the display in a geographical context permits the addition and correlation of additional geo-referenced overlays (e.g., weather data, exclusion zones, etc.).

Employed as a summary overview (e.g., as a team display up on the wall), this geo-spatial foundation allows the FVT to be employed as a team or supervisory tool to maintain situation awareness with respect to all flights traversing a given region. In this respect, the FVT represents a generalization of our prior GAMAT visualization capabilities toward multiple uses and collaborative support (cf. Chapter 1.3).

Employed on a single workstation (e.g., by a flight planner), the FVT similarly provides the basic display capabilities necessary to permit a planner to review one or more routes (and, e.g., evaluate their geographical range(s)) or to review a given geographical expanse (and, e.g., evaluate what flights are traversing it). Particularly when used by an individual flight planner, the FVT concept is intended to extend beyond a passive visualization aid. It is intended to also provide an interactive tool for generating and manipulating route depictions in the course of the planning process.

This dynamic / interactive aspect of the FVT concept is to be implemented so as to provide for:

- Direct importation and display of routes based on data from other TACC assets (most particularly ACFP)
- Direct manipulation of ACFP routes on the FVT map display
- The ability to select a route (or a segment of a route) via common "point and click" tactics
- The ability to implement route modification(s) via "grab and drag" tactics

- The ability to immediately see the effects of direct manipulation in terms of updated route parameters (as displayed in the auxiliary information displays and / or outboard palettes)⁵⁹

By shifting the primary flight planning modality from free-form text editing to contextually-constrained visual editing, the FVT concept is designed to:

- Minimize the cognitive burden of imagining a route based on a purely textual description
- Increase the number of (geo-spatial) cues that the planner may readily correlate with a depicted route
- Increase the probability of the planner's recognizing constraints, opportunities, etc., based on this increased cueing
- Minimize the risk of planners overlooking obvious opportunities, conflicts, constraints
- Minimize the risk of procedural and conceptual digressions by providing geo-correlated feedback on route manipulations

Geo-Visualization Controls / Tools

These are the general display controls grouped together and positioned above the central display window. This set of elements provides the user with the means to manipulate the central geo-visualization display itself and to select / manipulate areas or objects on that display using direct manipulation techniques. The proposed layout of this component's elements is illustrated in Figure 1.6-2.



Figure 1.6-2: FVT Geo-Visualization Controls / Tools

(Not to Scale)

The specific elements subsumed in the geo-visualization control / tool set include:

- Left / Right buttons (on ends) permit rapid shifting of map frame laterally.

⁵⁹ Full illustration of this interplay between the FVT and the outboard palette(s) will have to be deferred until a representative such palette (the Flight Planning Palette) is introduced later in this chapter.

- Multi-directional 'nudge' buttons permit incremental shifting of current map image in 8 directions.
- Zoom buttons (magnifying glass icons) permit reduction / magnification of current map image with current center point.
- 'Arrow tool' (default) designates cursor as selection implement.
- 'Marquee tool' allows user to designate a rectangularly-delineated set of elements (within the topmost display layer).
- 'Lariat tool' allows user to designate an arbitrarily-delineated set of elements within the topmost display layer.
- 'Crosshairs tool' allows user to designate a point around which to re-center the map display.

Layer Display / Controls

The 'value added' to the central geographical display lies in the various layers which can be flexibly invoked and arranged for overlay atop the basic map. The map alone is not all that informative. What makes it informative in the context of the work (e.g., the flight planning tasks) is the ability of that geographical context to interrelate the diverse elements (e.g., weather, route specifications, airfields) comprising the critical aspects of the work activity's decision making processes. As such, the Layer / Display Controls component of the FVT is more than simply a graphic display controller. It is in effect the primary means by which the user fuses multiple data objects into relevant 'information'. Phrased another way, the layering tactics provide direct aiding for 'sense making' within the extremely complex decision space of flight planners and other members of the TACC team.

This means that the Layer / Display Controls must be capable of both (a) addressing the potential complexity of the multiple data types employed and their interrelationships as well as (b) affording the user the simplest and most direct possible tactics for grappling with this complex data set. This in turn means that the design of this FVT component must provide the user maximum cueing and manipulation with minimum visual and procedural complications. The WCSS concept for this subsidiary FVT function is illustrated in Figure 1.6-3.

The basic features of the form and layout of the Layer / Display Controls component include:

- Listing of available layer sets as discrete composite units⁶⁰
- Within each layer set, an enumerated list of available layers

⁶⁰ The term 'layer set' is used here to denote a collection of layers grouped according to taxonomic affiliation. The set of layer sets employed in the FVT is intended to reflect the categorization schema outlined earlier in Chapter 1.6.

- Arrows / markers denoting layer set display state - i.e., 'collapsed versus expanded'.⁶¹
- Color coding for each layer set / layer entry such that (e.g.):
 - Gray / White = Inactive; Color = Active⁶²
 - Green = Active / Status OK; Red = Active / Alert Noted⁶³

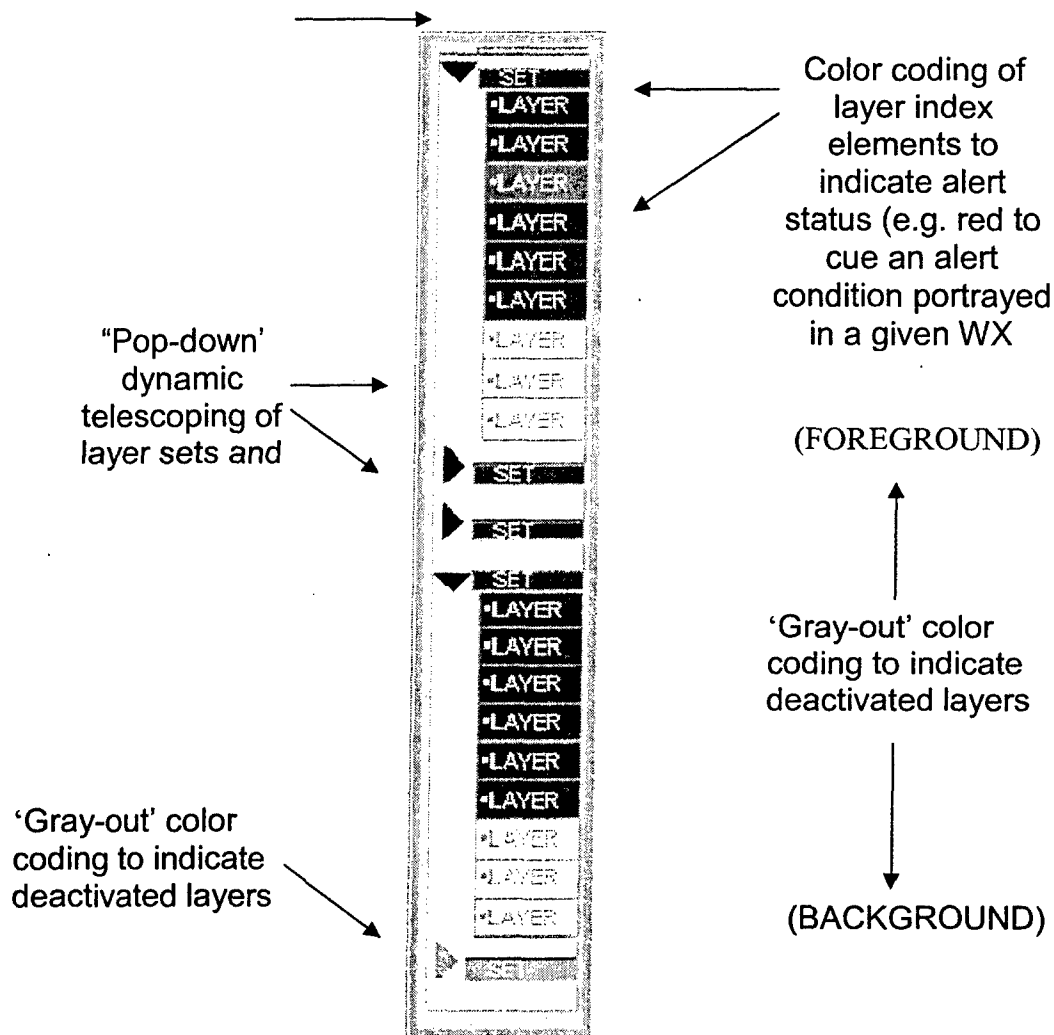


Figure 1.6-3: FVT Layer Display / Controls

(Not to Scale)

⁶¹ In other words, a 'collapsed' layer set is designated by the layer set label / tag alone. An 'expanded' layer set is comprised of the category (layer set) designator plus the indexes / tags for each of the subsidiary layers in that set.

⁶² This part of the color coding cues the user on the pragmatics of FVT state (i.e., which layers are 'in play' at any given moment).

⁶³ This part of the color coding cues the user on the relevant status of the work subject matter (e.g., routes and constraints on routes) as correlated with the layer(s) to which he / she should direct attention for further assessment.

As illustrated in Figure 1.6-3, the vertical ordering of the layer set / layer indicators is designed to actively cue the user on the ordering of said layers on the central geographical display. Those layers at or near the top of the vertical listing correspond to the 'foreground', and those at or near the bottom correspond to the 'background' relative to the map display. These layer and layer set indexes / tags are not fixed in position. They can be moved upward and downward (as described below) to reflect the particular ordering of the geo-visualization layers in the center of the FVT.

Finally, these layer indicators are intended to function as interactive 'handles' allowing the user to directly manipulate the geo-display to suit his / her requirements. The specific tactics prescribed so far for such manipulations are as follows:

- Each layer set tab can be 'grabbed and dragged' (mouse-over + button hold + drag) up or down to rearrange relative 'vertical' ordering of the sets.⁶⁴
- Each layer tab can be X-clicked (X = right or left or double) to pop up layer control / preferences widgets.⁶⁵
- Each layer set / layer tab can be Y-clicked (Y = option other than X) to toggle that element between 'active' and 'inactive' state.⁶⁶

Through combining and simplifying the layer display and control features (relative to the WCSS-GWM), the FVT WCSS concept affords the user an even greater degree of direct aiding and control than even that well-accepted design provided. This streamlining of layer features is necessary to minimize the cognitive burdens and maximize the situation awareness-facilitating functions this component of the FVT is intended to perform.

Auxiliary Information Displays

In the upper right corner of the FVT design concept we have provided certain additional data displays to afford the user additional information. This additional information is needed to (a) notify the user of certain background data of global relevance; (b) cue the user as to what he / she has selected as being of most immediate interest on the central geo-visualization display; and (c) provide summary cueing data on that selection. The initial design concept incorporates three subsidiary components of this auxiliary information presentation, each corresponding to one of the points cited. The arrangement of this set of components is illustrated in Figure 1.6-4.

⁶⁴ Such direct manipulation of the layer 'tag' vertical ordering is intended to result in an immediate corresponding change in the background-to-foreground ordering of the layered graphic data on the central geo-visualization display.

⁶⁵ Such widgets are to be provided to allow users to adjust settings on the general features of the layers themselves (e.g., transparency, scaling, and so forth).

⁶⁶ This feature allows users to readily invoke and dispense with individual layers or entire layer sets with a single select-and-click tactic.

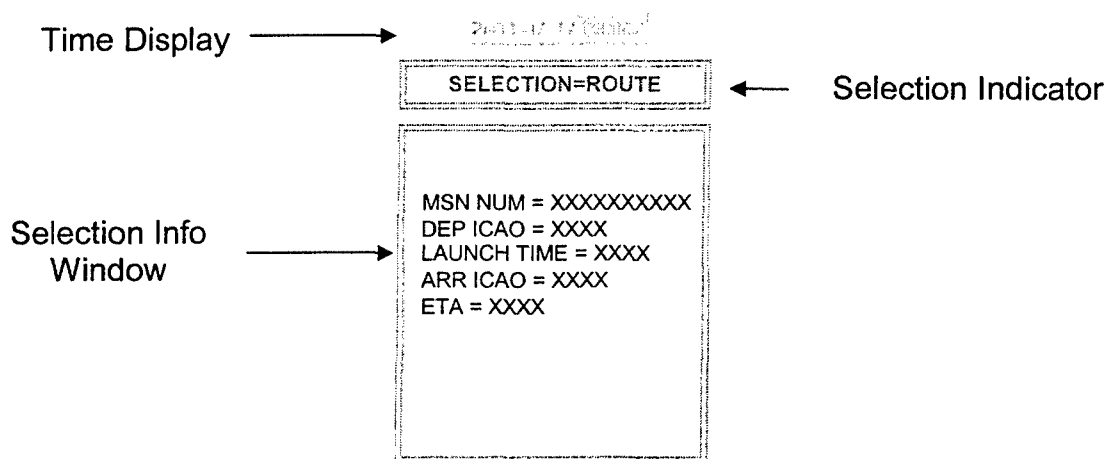


Figure 1.6-4: Auxiliary Information Displays

(Not to Scale)

These subsidiary components are as follows:

- The Time Display (topmost) gives the standard date and time to remind the user of this critical parameter.
- The Selection Indicator (middle) provides a cue for what kind of item is currently highlighted / selected on the central geo-visualization display.
- The Selection Info Window (bottom) is a space within which summary data on the selection is provided.

The Selection Indicator and Selection Info Window parts of Figure 1.6-4 provide an illustrative case of how these elements are intended to aid the user. In this illustrative case, a mission route is selected on the central display. The Selection Indicator cues the user that a 'Route' is the current selection. The Selection Info Window provides summary data on the mission / flight associated with the selected route. The summary data provided in the Selection Info Window will, of course, vary with the class and identity of the item(s) selected on the graphical display.⁶⁷

⁶⁷ One might well bring up the question of whether or not the functions of the Auxiliary Information Displays (particularly the Selection Indicator and the Selection Info Window) could just as well be accomplished through interactive pop-ups on the central geo-visualization display itself. This is a reasonable point to ponder. However, reliance on pop-ups alone in the context of a potentially very complex visual display could prove frustrating to users. The elements of this Auxiliary Information Display area provide a persistence which is necessary should the user need to select something on the central display, then move his / her attention elsewhere (e.g., layer controls or an outboard palette). This persistence affords the user a capability for being reminded of 'what I last selected' that cannot easily or cleanly be afforded using dynamic pop-ups alone.

'Outboard' Window Selector

As a general-purpose visualization aid, the FVT is capable of being used for a variety of functions and by a variety of roles within the TACC team. As discussed earlier, it is intended to be able to be employed as both a management oversight display, a group situation awareness display, and an individual planning aid. This generality comes at the expense of a trade-off. Because it is general in scope and function, the FVT cannot simultaneously serve as a specialized tool for each and every role for whom it is intended. Even though the FVT is designed to serve as a summary visualization display, it cannot supplant all the other tools in the current and prospective TACC IT inventories. There will always be a potential need to invoke another tool to (e.g.) edit crew papers. Similarly, there will always be a potential need to invoke (e.g.) CAMPS or GDSS-2 to check on details associated with a given mission.

As a result, the FVT concept is designed to be a central component of a flexible suite of tools supporting the TACC team. It provides the main 'window on the missions in the world', and will presumably be a regular (if not persistent) presence on a variety of desktops and other displays. Other tools and aids will need to be flexibly invoked from the FVT as requirements dictate. To provide for such invocation of 'outboard' aids, the FVT incorporates an Outboard Window Selector component in its lower right-hand corner. The Outboard Window Selector concept is illustrated in Figure 1.6-5.

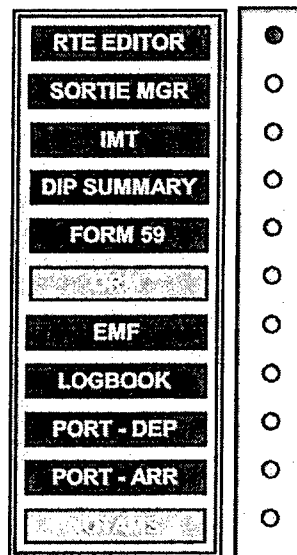


Figure 1.6-5: 'Outboard' Window Selector

(Not to Scale)

As Figure 1.6-5 shows, the Outboard Window Selector provides a reference list of additional windows / displays / palettes the user can invoke as needed.⁶⁸ Some of these are for reference purposes, while others are 'working spaces' for entering / creating / modifying mission-related data. The vertically-order set of rectangular buttons are used to invoke these outboard windows / palettes.

These buttons are color-coded to indicate (context-sensitive) relevance to the user's position and/or current state of his / her selection (cf. the discussion of the Selection Indicator above). For the sake of illustration, Figure 1.6-5 uses 'blue' to connote a 'relevant' asset and 'gray' to connote an asset of no or very limited relevance.⁶⁹ Let us illustrate this concept by reference to the illustrative state of the Selection Indicator discussed above. In this case, the 'route-centric' selection de-emphasizes the ORM and NOTAMS, because neither of these categories of data pertains to 'routes' per se.⁷⁰

Color-coded indicators (the small circular elements to the right) cue the user as to which available outboard options have been invoked. In Figure 1.6-5, only the Route Editor (discussed later) has been invoked. This feature is included to aid the user in managing a potentially large number of outboard aids within a finite display area.⁷¹ If one were to include multiple color-coding for these indicators, the FVT could provide the user with alert status cueing with respect to the outboard palettes as well. For example, a 'colored' indicator would cue the user that the associated outboard asset was 'open / active'. If the indicator color was green, the user would know from the FVT alone that no outstanding alert conditions were flagged on that outboard asset. Conversely, if the indicator color was red, the user would be cued that an outstanding alert condition had been flagged, and (e.g.) he / she could simply hit the associated button to bring that particular outboard asset to the foreground.

Work-Centered Rationale for the FVT + Outboard Assets Architecture

The reorganization of our WCSS designs during Phase II was deliberately aimed at modularizing work support features to provide a suite or toolkit capable of supporting the breadth and diversity of TACC team members' activities. Recall that the earlier discussion on collaboration concluded that TACC didn't need a means for realtime joint work activity so much as a means for keeping all team members 'coordinated' with respect to the subject matter (missions, routes, etc.). This theme was an important factor in deciding to pursue modularity and flexible interoperation rather than a range of single 'all-in-one' WCSS concepts, all somewhat redundant and each tailored to a specific position or role. The toolkit architecture presented here is judged to be the optimal approach for supporting the entire TACC team in the most comprehensive and coherent fashion. From the perspective of functionality and work-centered support, the reasons for this claim include:

⁶⁸ The particular set of items illustrated in Figure 1.6-5 represents only a notional list generated for the sake of illustration. A definitive list was not developed during GAMAT Phase II.

⁶⁹ The color-coding to cue the user on contextual relevance is not meant to limit the user's options for invoking outboard assets. All the buttons are intended to be 'functional' at all times. This color-coding is only an overlay or gloss for the purposes of guiding user attention and minimizing the cognitive burden of trying to figure out which outboard assets are most relevant to drilling down on the item (e.g., a route) he / she has designated as the current selection.

⁷⁰ To further illustrate, had the user's selection been (e.g.) a 'weather element', the WX-related ORM would have been highlighted as 'relevant'. Similarly, had the selection been an individual 'airfield' the NOTAMS button would have been highlighted as 'relevant'.

⁷¹ As demonstrated in the IFM project (2000 - 2001), the issue of display overload within finite screen space was, and still is, an important human factors problem in TACC operations.

- This *minimizes* the number of redundant features otherwise replicated across a set of role-specific 'all-in-one' WCSS units.
- This *minimizes* the scope and complexity of updates and re-designs (through modularity).
- This *maximizes* 'common look and feel' and fosters a better basis for TACC team collaboration.
- The core visualization (FVT) provides a basis for management viewing things just as ops staff do.
- Starting from the common work domain visualization afforded by the FVT, the user(s) can freely and flexibly invoke additional visualizations and / or tools.
- This *maximizes* the ability of each TACC user to mix 'n' match visualizations and tools to fit his / her current issue(s) and situation(s)...

More generally, this approach has benefits with respect to TACC operational administration, oversight of its technological infrastructure, and the ability to evolve that infrastructure as time goes on. These more enterprise-wide benefits will result from the following factors:

- Keeping the core / common visualization component separate allows for independent refinement of the 'outboard' tools.⁷²
- This *maximizes* the opportunities for fine-tuning these tools to suit current requirements.
- This *maximizes* the tractability of modifying / refining these tools over time.
- Allowing common (read) access to each other's tools permits TACC team members (including management) to view status and issues in a coherent and mutually-understandable way.⁷³
- This approach pushes the notion of the 1990's-era concept of 'common operating picture' to achieve its originally intended payoff - 'commonly-pictured operations' (i.e., coordinated situation awareness, decisions, and actions).⁷⁴

⁷² In other words, modularity is the recommended strategy for mitigating the historical vulnerability of TACC operations to delayed improvement by having to wait on global revisions to large all-in-one information systems.

⁷³ This is a deliberate strategy to promote better 'coordination' (cf. discussion of collaboration in TACC) both 'horizontally' across roles / positions and 'vertically' through the administrative strata.

⁷⁴ Indeed, this theme of 'commonly pictured operations' can be seen as the top-level outcome of a work-centered approach prioritizing the work itself as the subject matter (as contrasted with the mechanics of operating one or another specific information system).

The Route Editor

Now let us move on to consider a specific tool intended to serve as one of the outboard aids invocable from the FVT. During the last months of GAMAT Phase II the single such outboard tool most closely linked to our focal flight planning task was initially designed and briefed. This tool was labeled the Route Editor, because it was designed to offer flight planners (and other personnel conducting notional flight planning) capabilities to:

- Generate or invoke an ACFP route specification associated with the given sortie
- Edit the text specification for that route
- Display the ramifications of a new or modified route specification in a graphical display (on the FVT)
- Store 'snapshots' (local copies) of a route specification for subsequent review and evaluation
- Cue the user on the progress and status of his / her (re-)planning work using the sort of 'checklisting' structure initially introduced for the flight managers in the IFM project
- Manage interactions and synchronization between the state of this outboard tool and an associated FVT.

The Route Editor was deliberately designed to meet the objectives outlined earlier in this report with regard to the flight managers' Sortie Manager (which derived from an IFM project WCSS concept). The Route Editor represents a more generic version of the Sortie Manager from which any FM-specific options and features have been either generalized or eliminated. The basic form of the Route Editor is therefore very similar to the Sortie Manager. This basic layout of the Route Editor is illustrated in Figure 1.6-6.

Route Editor: Mission Number XXXXXXXXXXXXX

Info Tools NOTIONAL ☒ ACTUAL

MSN NUM DEP ARR LAUNCH TIME MSN TYPE A/C TYPE

FVT IS: ☒ COUPLED ☐ DE-COUPLED

☒ CREATE ROUTE

☐ EDIT ROUTE

PUSH TO FVT

CURRENT FVT NEW FVT

PULL SNAPSHOT FROM FVT

AS: SNAP-7

AS: 'My Notional'

• ORIGINAL

- PUSH-1-DATE-TIME
- PUSH-2-DATE-TIME
- SNAP-1-DATE-TIME
- PUSH-3-DATE-TIME
- SNAP-2-DATE-TIME
- SAVE-'My Notional'-DATE-TIME

TACC-DIP-Planning

WORK AREA:

The display / editing / interaction area for each step invoked in the planning process

Plan/Edit
Controls

Figure 1.6-6: The Route Editor Concept

(Not to Scale)

The Route Editor palette is subdivided into three subareas - a Header, a Working Area, and a Plan / Edit Controls area. The Working Area is a general purpose window for the presentation and interactive editing of text (e.g., route specifications). It is into this Working Area that route data associated with a given sortie will be pulled for review, evaluation, and manipulated. The other two subareas require additional description and discussion in the following subsections.

Header Subarea

The Header subarea is positioned along the top periphery of the Route Editor palette. This header contains both display elements and interactive elements. The display elements provide the user with basic data on the particular mission / sortie being addressed in the Route Editor. The interactive elements allow the user to (a) flag the current route editing work as 'notional' / 'actual' and (b) to couple the state of the Route Editor to an associated FVT display. The basis for grouping these particular elements in the Header subarea is that these things pertain to the status and the subject matter of the current Route Editor itself, and not to the content being reviewed and / or manipulated within the Editor. The elements of the Route Editor's Header are illustrated in Figure 1.6-7.

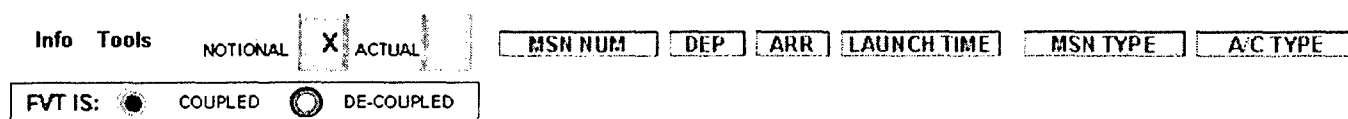


Figure 1.6-7: The Route Editor Header Elements

(Not to Scale)

A summary description of the Route Editor Header elements includes the following overview comments:

- Basic menus (upper left) allow for local control of Route Editor palette within the presumptive Windows operating environment.⁷⁵
- Checkboxes for 'Notional' versus 'Actual' allow specification of (and cueing for) the relative status of the route product being addressed in this Route Editor. This feature permits the user to use the Route Editor as a sketchpad for (e.g.) notional flight (re-)planning without running the risk of publishing a local or transient work product as if it were final and actionable.
- Basic information text windows (along top) provide on-palette cueing for the most important 'factoids' relating to the mission for which the given route is being displayed.⁷⁶
 - Mission number

⁷⁵ The inclusion of such menus in the WCSS concept sketches is a concession to the Windows environment in which the GAMAT prototyping work has been conducted. These menus are therefore not strictly components of the WCSS design concept itself. Because they are peripheral 'stubs', they will not be discussed further in this report.

⁷⁶ The set of informative factoids chosen for inclusion in the Route Editor header is based on the set of referents most commonly cited as key descriptors for a given mission during our last 5 years' work with AMC/TACC.

- Departure port (ICAO)
 - Arrival port (ICAO)
 - Launch time
 - Mission type
 - Aircraft type
- Manually-selectable 'Coupled / De-Coupled' radio buttons permit user to disengage Route Editor from interactive linkage with FVT (if need be).⁷⁷

The inclusion of both (a) notional / actual flagging and (b) FVT coupling status may seem somewhat redundant at first glance, but it isn't. Flagging a route specification as either 'notional' or 'actual' (i.e., 'official' or 'actionable') is a matter of designating the work product *content* in the context of its potential usage. Designating coupled status with regard to a separate FVT, on the other hand, is a matter of designating whether or not the current state of Route Editor content (perhaps not yet ready to become a final 'product') is to be graphically visualized in the course of generating such a work product. As such, these are two distinct things, and the controls pertaining to them must be similarly distinguished.⁷⁸

Plan / Edit Controls Subarea

The Sortie Manager which provided the conceptual precedent for the Route Editor was specifically configured to reflect and to cue the flight manager on the canonical stepwise course of his / her flight planning process. A series of color-coded indicators, checkboxes, and text display elements were combined to provide a running summary of what steps had been completed, which steps were pending, and some quick cueing on data critical to certain of the steps. This work-centered design theme was carried forward into the Route Editor WCSS concept.

⁷⁷ This feature allows the user to 'couple' an FVT to the Route Editor such that modifications made textually to a route specification can be graphically visualized. As will be seen shortly (in the discussion on the Plan / Edit Controls subarea) this may be the FVT from which the Route Editor was initially invoked or a new one generated solely as an adjunct to the Editor palette.

⁷⁸ For example, a 'quick fix' or straightforward addition of text to a route specification might not need to motivate the time and processing required to generate an associated FVT visualization. This might apply regardless of whether the route specification at issue is 'notional' or 'actual'. As such, FVT visualization may be 'optional', whereas designation of plan status is something that must always be done.

However, this does not mean that the Route Editor's procedural cueing and informative elements are the same as (or even very similar to) those portrayed on the Sortie Manager palette. There are some important differences between the two WCSS concepts. The Sortie Manager evolved from a concept specifically designed for flight managers. At the time of the WCSS effort generating this concept (2000 - 2001), flight managers had no capability for graphically visualizing route specifications. They worked with ACFP flight plans provided in draft form by the flight planning shop or generated by the flight managers themselves. At the time of the IFM project our WCSS analysis was focused on the relatively simplistic FM function of generating and issuing crew papers for each of a relatively few missions or sorties previewed specifically pre-selected for FM processing. As such, the FM work process studied and analyzed 4 years ago did not incorporate the full range of complexities which confront mission planners, DIP planners, flight planners, and even the proliferating population of flight managers.

In other words, the original WCSS concept seminal to the Sortie Manager was designed to support a fairly unilinear documentation process within which graphic visualization was no more than a pipe dream and few if any routing alternatives or options were ever generated for consideration. The scope of design has now grown to encompass the TACC team generally, and graphical support is now a reality (at least in prototype form). The arrival of feasible route visualization capabilities means that a route planning tool needs to be capable of interacting with its visualization component(s). Our GAMAT Phase II prescription for modularization of WCSS tools means that this capability has to be tailored to account for interactions with separate but referentially and functionally interlinked on-screen tools. To account for the decision processes of all relevant TACC team members, our new route planning WCSS needs to be able to handle multiple (and potentially numerous) alternative or optional candidate work products. Finally, with our scope of design and implementation expanded to address intra-team (hence inter-role; inter-unit) collaboration, the new WCSS concept has to provide for sharing and forwarding both intermediate and final route planning products.

The Route Editor's analogue to the Sortie Manager's 'checklist' display and control area is the Plan / Edit Controls subarea illustrated in Figure 1.6-8.

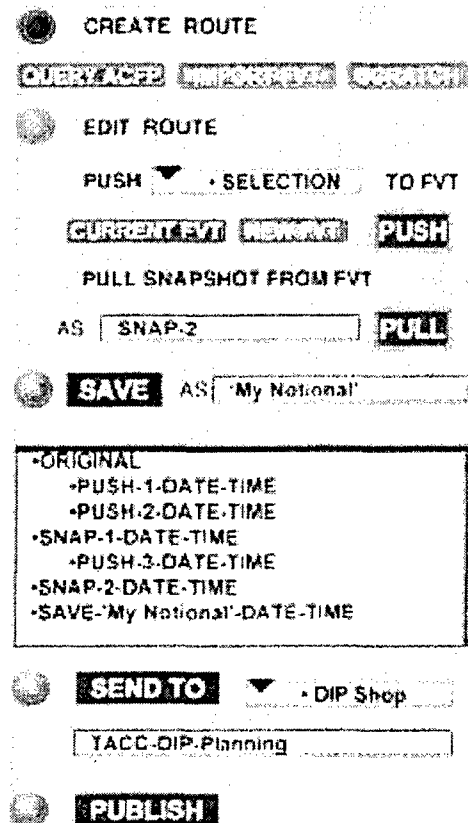


Figure 1.6-8: The Route Editor Plan / Edit Controls Subarea

(Not to Scale)

The main descriptive points to be made about this design component and its intended functionalities are as follows:

- As was done in the Sortie Manager, the elements' vertical organization reflects overall task / process flow, with earlier / precedent steps being portrayed 'uppermost' and later / subsequent steps being portrayed 'lowermost'.
- Circular indicators associated with each major process step / option cue the user on current status for that step / task (Green = Done; Yellow = In Process; Gray = Not Yet Done; Red = Alert / Prompt for Required Action).
- Initial route specifications can be entered in 3 ways:

- Query ACFP (yielding a set of candidate routes)
- Import ('pull') it from a current FVT selection (i.e., show text of route highlighted on map visualization)
- Edit it from scratch (including pasting in text)⁷⁹
- Editing is done in Work Area using conventional text processing tactics.
- Generating a graphical representation of the current route specification is done by 'pushing' it to the extant (or a new) FVT.⁸⁰
- Importing a FVT - modified route spec is done by 'pulling a snapshot' back into the Route Editor.⁸¹
- A 'Save' button permits proactive storage of a draft route spec (with user-defined labeling as option).
- Each 'push' and 'pull' action automatically triggers a similar storage action (without having to hit 'Save').
- These tactics allow the user to generate and accrete a set or list of candidate route specifications for review, further editing, and / or export as a final planning product.
- The accreted list of draft route specs is organized in accordance with chronological origin (allowing trace of planning process).
- First on the list is 'Original' (first-pushed), and last will be the latest 'Save'.⁸²
- Intermediate draft products are listed as 'Push' and 'Snap'(-shot) items.

⁷⁹ Though this scratch option may seem archaic and something to be eliminated, our KA during GAMAT Phase II repeatedly indicated that proficient flight planners sometimes do just this - particularly when dealing with novel routing conditions or when having to operate under time pressure.

⁸⁰ The reason provision was made for designating current versus new FVT displays is to afford users a number of opportunities which may be needed, depending on role and circumstances. For example, the flexibility to generate multiple 'slave' FVT's would give a flight planner the ability to visualize and compare a set of candidate routes. To give another example, if the extant FVT is in collective use (e.g., as a team display), it would be unwise to have one team member 'posting' intermediate or tentative routes on such a general situation awareness display.

⁸¹ Although this 'pulling a snapshot' capability is functionally identical to an initial 'import' action, there is an important distinction to be drawn between the two acts. The 'import' is an optional tactic for bootstrapping work done with the Route Editor. A 'snapshot pull' is a mandatory tactic for capturing the state of an FVT visualization as an intermediate work product. The necessity for drawing this distinction is reinforced by the fact that we must allow for more than one FVT to be involved in a particular route editing / planning task.

⁸² This ordering is specified deliberately to allow the user to index the candidate route specifications in accordance with the chronological order in which he / she addressed and / or processed them. This correlates intermediate work product indexing with in-task experience and minimizes the cognitive burden that would result if the user were required to index the potentially sizeable candidate specifications list using arbitrary labels.

- Although items accrete to this candidate list only via Push / Pull / Save / Publish actions, they can be deleted directly.⁸³
- When 'done', user can forward current route spec to other TACC team members via 'Send To'.
- As appropriate, user can use 'Publish' to accrete the route spec to TACC team IT assets (e.g., Electronic Mission Folder).

These last two features ('Send To' and 'Publish') allow the Route Editor's users to participate in the larger collaborative context of the TACC team. Using the 'Send To' option, a user can forward a candidate specification for review / evaluation / approval by another team member. To given one pertinent example, this could be the primary mechanism by which a mission planner forwards a notional route / flight specification to the DIP shop for initial review. Using a separate 'Publish' capability allows the user a discrete means for exporting his / her final route planning product to the TACC team data infrastructure assets. Differentiating between 'Send To' and 'Publish' accounts for the possibility that the user may have to circulate a draft route plan one or more times before committing to a final version.

An Illustrative Use Scenario for the FVT / Route Editor Combination

To illustrate how the FVT and the Route Editor are intended to be used, let us return to our earlier recommendation that a mission planner be enabled to generate his / her own notional flight plans. Figure 1.6-9 illustrates the basic process path for accomplishing this using the combination of the FVT and a Route Editor.

⁸³ This feature allows the user to proactively and easily eliminate candidate specifications as he / she determines they are of no further importance to his / her task.

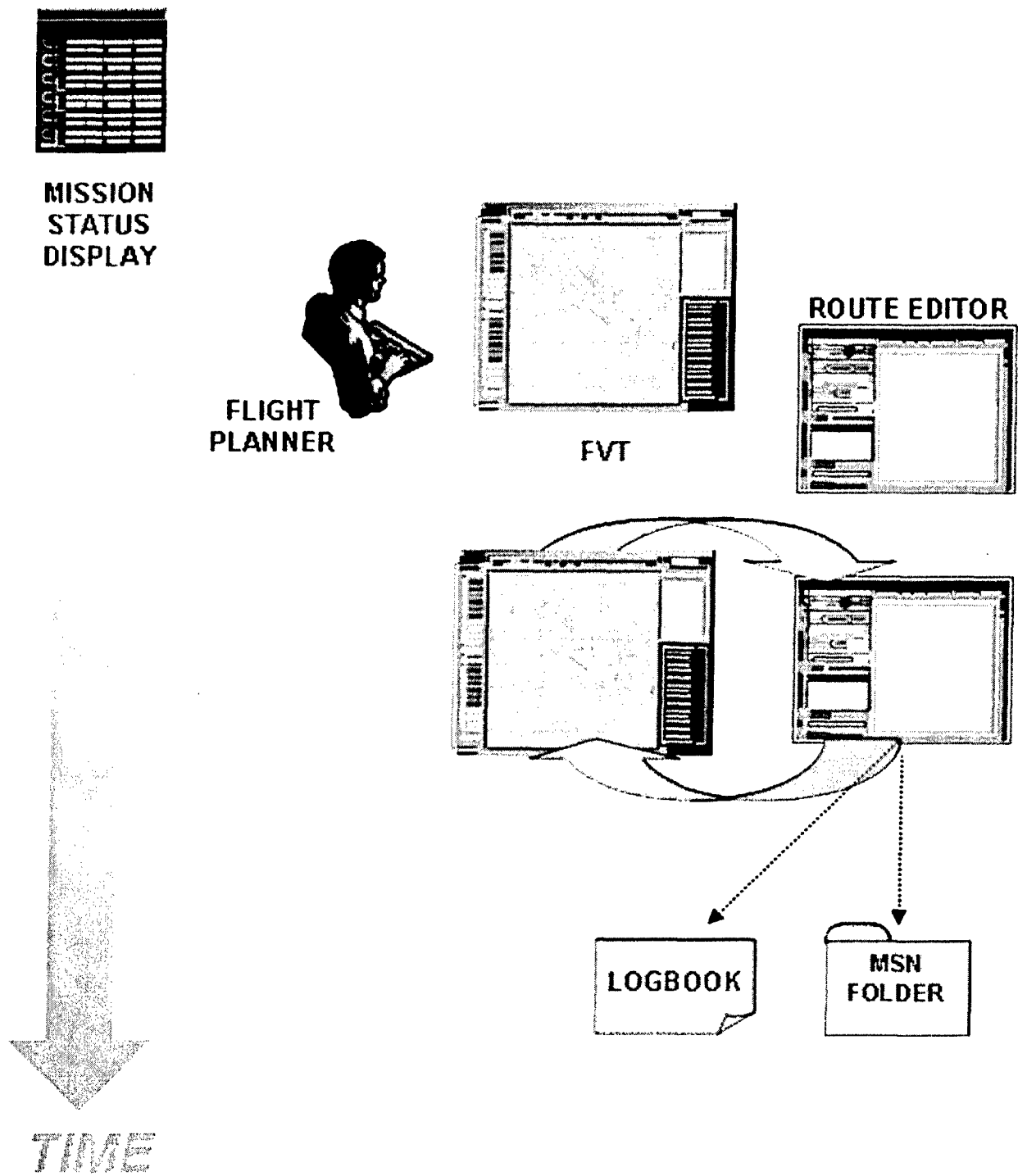


Figure 1.6-9 A User Scenario for the FVT and Route Editor

First, the mission planner identifies and selects a pending mission from the Mission Status Display (his 'to-do list'). Invoking an FVT in the context of this particular mission record gives him / her a geo-referenced visualization display for the region to be traversed. By invoking a Route Editor from the FVT, the mission planner is presented with a working palette into which he / she can (e.g.) import an ACFP flight plan, edit it, and save it as a notional work product. Using the interlinking between the FVT and the Route Editor, he / she can both display the text specifications derivative of the FVT's graphically-displayed (and / or manipulated) route and conversely display the graphical representation for textual route specifications being edited in the Route Editor. Once he / she is satisfied with the specification, it can be saved or published to (e.g.) the Logbook or the Electronic Mission Folder.⁸⁴

⁸⁴ In addition, he / she can forward the candidate specification to the DIP shop using the 'Send To' feature so as to get an initial review of the prospects for diplomatic clearances.

1.7 Work-Centered Analysis and Design Recommendations for TACC Flight Planning and Flight Planning-related Collaboration Summary

The GAMAT Phase II flight planning-related analysis and design work covered a diverse set of topics and much conceptual ground. The two primary foci for this portion of the Phase II work were (a) opportunities for flight planning related collaboration in the TACC (although much is generalizable beyond a strict relationship to flight planning) and (b) providing WCSS design concepts aimed at supporting the flight planning function. These two foci were intertwined and had to be addressed with respect to each other. For one thing, the flight planning function is arguably the most centrally-critical one in the overall TACC planning and execution process path. As such, changes to the flight planning phase of the process path have major implications for the TACC team (and their collaborative prospects) in general. Conversely, some of our perceived leverage points for improving overall TACC team performance (e.g., earlier generation of notional flight plans) required innovations which would extend flight planning functions to other positions and units.

As discussed in Chapter 1.3, the GAMAT Phase II work produced the following analytical results with respect to TACC team collaboration:

- Identification of temporality as the primary context for addressing constraints on sorties
- Identification of the need to eliminate 'blind spots' that prevent individual roles and positions from maintaining situation awareness on the overall TACC workstream and the mission 'cases' comprising that workstream
- Specific interventions (e.g., mission planners generating their own notional flight plans) which could improve overall TACC team performance
- A review and analysis of the extent to which our precedent WCSS concepts from HISA, IFM, and GAMAT Phase I could be extensible to support the entire TACC collaborative team rather than the particular roles for which they were originally targeted.
- An assessment of what specific features could be preserved (and which needed to be extended or generalized) to achieve this collaborative objective.
- An assessment of the extent to which our novel and evolving WCD approaches and methods have permitted us to design for collaboration from the very beginning.

As discussed in Chapter 1.4, the GAMAT Phase II work produced the following results with respect to the flight planning function in particular:

- Identification of the main flight planning performance problems capable of being addressed and ameliorated using WCSS innovations.
- Specification of the particular WCSS interventions necessary to ameliorate these problems, including:

- Incorporation of realtime graphical visualization in the IT support aids providing the flight planning staff.
- Incorporation of new route manipulation capabilities leveraging this new graphical representation (e.g., via direct manipulation of on-screen elements).
- Renovation of the current and / or next-generation F2 Database (or equivalent) to permit addressing routes at a minimum of two levels of granularity.
- Leveraging the implied imposition of a more structured organizational schema for route data to make maintenance of the flight planners' route specification database both more efficient and more effective.
- Designing flight planning IT aids such that they were of utility to the broader population of TACC users (i.e., not designing solely for the experienced flight planners).
- Making provision for supporting other TACC players (most particularly the mission planners) with a capability for generating notional flight plans without having to request the flight planners do it for them.
- Illustrating the utility of facilitating TACC team situation awareness on constraint and alert conditions affecting mission / flight viability, but that are not directly and immediately inspectable with current individual tools.

As presented in Chapters 1.5 and 1.6, we generated new or next-generation WCSS design concepts intended to:

- make route rationale and constraints more visible;
- facilitate all TACC team members' abilities to understand, evaluate and revise a flight plan;
- afford mission planners more information on options and alternatives;
- allow more timely capture and presentation of information necessary for better situation awareness (SA);
- eliminate current 'blind spots' in the TACC process path;
- enable more proactive response across the organization;
- reduce mission delays and mission 'no-gos' and;
- provide aids to enable Flight Planners to more efficiently capture and maintain the corporate flight planning knowledge base
- Provide more expedient means for editing work products.

- Afford users a richer way to search / index the database of 'precedent routes'.
- Eliminate bottlenecks and delays by providing direct access to relevant work products (e.g., notional flight plans for DIP shop, Mission Planners).

The specific WCSS innovations prescribed in this report illustrate the intertwining of the collaboration theme and the flight planning focus in both their framing and their suggested payoffs to individual users, their units, and the TACC team as a whole.

1.8 Work-Centered Support System for Global Weather Management Spiral 2 Capability Design and Demonstration

Background

The first phase of the GAMAT program produced the first spiral of a demonstration capability of the Work-Centered Support System for Global Weather Management (WCSS-GWM). The WCSS-GWM was designed to mitigate the impact of changing weather conditions on near term planned and en route Air Mobility Command (AMC) missions by command and control personnel residing in AMC's central command and control facility, the Tanker Airlift Control Center (TACC). Because of their satisfaction with the support provided by the demonstration capability, many of the target users – the TACC/WXM Weather Forecasters and TACC/XOC Flight Managers – began using the demonstration capability to support a portion of daily operations in the TACC. As a result, additional analysis and capability was requested by AMC personnel to more efficiently support those operations. This provided research opportunities to experiment with expanding the basic WCSS-GWM framework to support larger user sets, and gain additional insight into the scalability of the basic WCSS-GWM framework.

The WCSS-GWM is a software client application designed to mitigate the impact of changing weather conditions on near term planned and on route Air Mobility Command (AMC) missions by command and control personnel residing in the TACC. Figure 1.8-1 shows the basic user interface configuration of the WCSS-GWM Spiral 1. The WCSS-GWM provides AMC personnel with a consolidated view of weather and air mission information along with and integrated into the context of the work being performed. It supports rapid, flexible and adaptive work through a mix of user interface form design and automation. It augments user cognitive capability by proactively monitoring relevant information, reporting potential exceptions and providing rapid and flexible ways to understand the potential problems constraints to enable rapid analysis and alternative course of action generation and decision making, while remaining organized with respect to multiple work threads (in this case airlift or tanker sortie planning and execution support).

In a more specific sense, the WCSS-GWM consists of two context coordinated panels – the mission detail panel and the mission summary panel, each providing distinct but related contextualized information that allows a user to remain in the proper context while examining problems from different perspectives – i.e., relative to specific categorizations and geo-spatial details and relative to summarial and related mission categorizations. It enables rapid fusion of flight path, weather and other relevant information as user selectable layers to enable rapid potential course of action generation to support problem resolution. It enables user-definable intelligent agent-based exception reporting and alerting when significant changes in weather phenomena are detected which may impact those missions. It also includes an Agent Management Tool (AMT) that allows users to flexibly define “watch areas” for specific weather events. It also provides a more general capability to define ‘exclusion zones’ and alert the user, when a mission track intersects an exclusion zone.

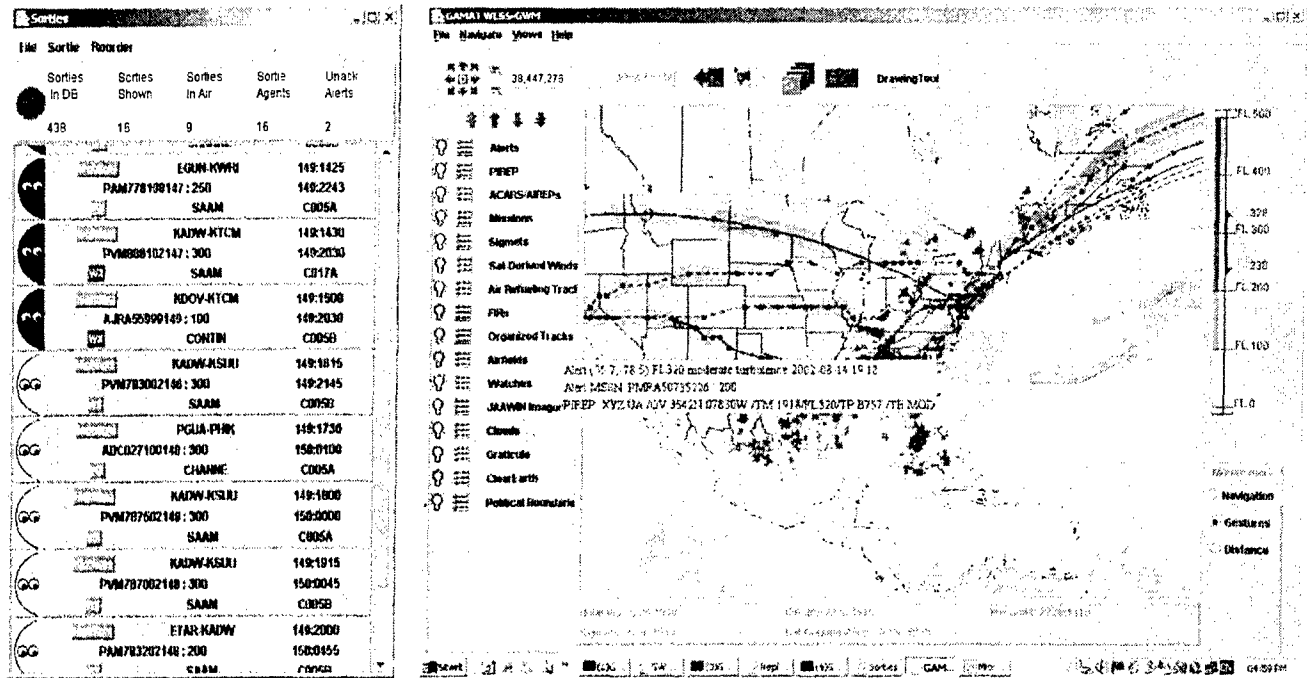


Figure 1.8-1: WCSS-GWM Spiral 1

A variety of innovations were made to the first spiral version of the WCSS-GWM to enable more efficient support for TACC operations and teams based on additional information learned during the GAMAT Phase II effort. Some of these capabilities were demonstrated in spiral 2 of the WCSS-GWM.

Work-Centered Support System for Global Weather Management (WCSS-GWM) Spiral 2 Demonstration Capability

This section summarizes the WCSS-GWM Spiral 2 demonstration capabilities. For more detailed information about the WCSS-GWM Spiral 2, see the *WCSS-GWM Users' Manual* and the *WCSS-GWM Users' Manual*.

The primary groupings of changes that distinguish the WCSS-GWM Spiral 2 (Figure 1.8-2) capability from the WCSS-GWM Spiral 1 capability were the:

- Addition of new data sources and data source update rate changes
- Additional information fusion capability instantiated as 'layers'
- Additional alerting capabilities
- User Interface display and control changes
- Software architecture changes

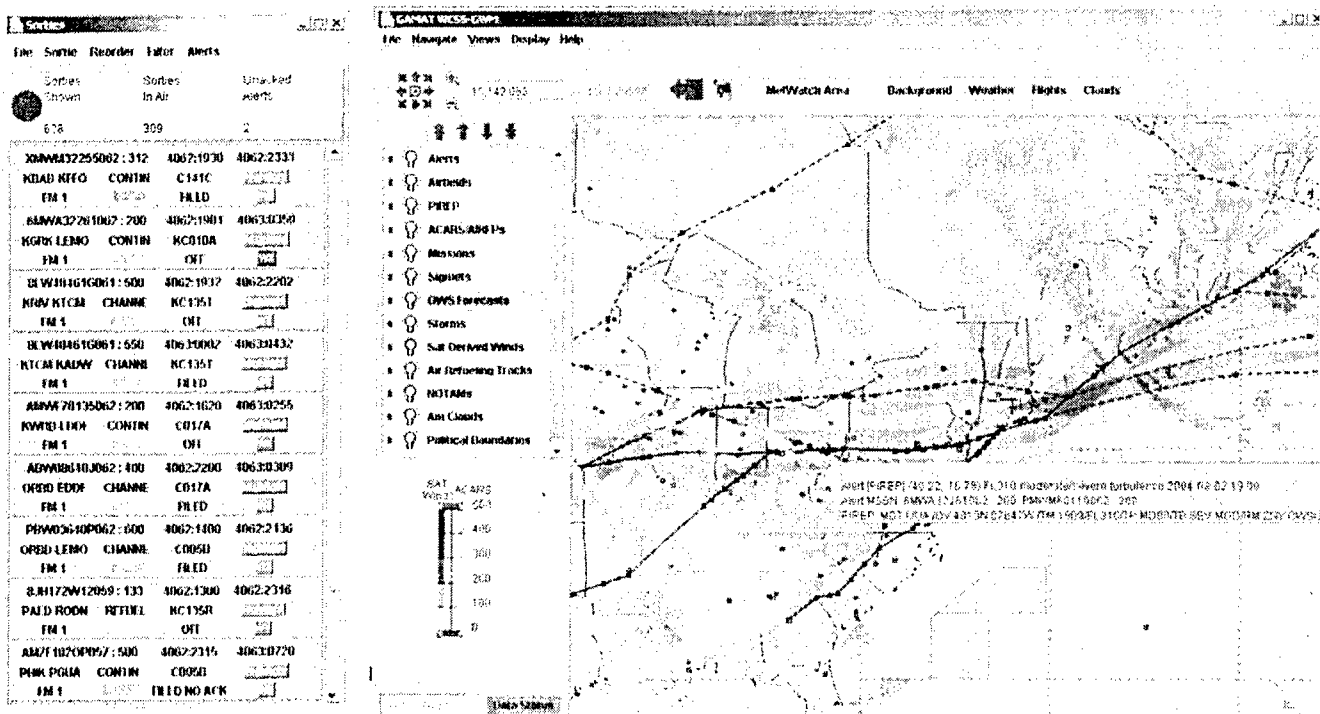


Figure 1.8-2: WCSS-GWM Spiral 2

Data Source and Update Rate Changes

The WCSS-GWM is designed as a network-centric client application. It was designed as an independent client application that utilizes data from a variety of sources to provide comprehensive work support aiding. The work-centered requirements analysis determined that in order to most efficiently support the target work activities, multiple data sources not residing in any single system were required to support the functionality instantiated in the user interface. Following are the data sources utilized by the WCSS Spiral 2: (Changes from the Spiral 1 version are noted.)

- 15th Operational Weather Squadron forecasts from the 15OWS distribution server as created in the Operational Weather Squadron Production System II (OPS II). This feed was added during Spiral 2 development.
- Tropical Storm tracks and forecasts from the Fleet Numerical Oceanography Center (FNMOC) as they are created. This feed was added during Spiral 2 development.
- Weather-related Operational Risk Management (ORM) integration provided by the Global Decision Support System (GDSS). This feed was added during Spiral 2 development.
- Flight path information from the Global Decision Support System (GDSS) Integrated Flight Management (IFM) backup database via a RIDL report every 4 minutes. Spiral 1 received this feed every hour.

- Aircraft Communications and Reporting System (ACARS), Pilot Reports (PIREPs), Aircraft Reports (AIREPs), Meteorological Terminal Air Reports (METARs) and Terminal Aerodrome Forecasts (TAFs) from the 15 Operational Weather Squadron (15 OWS)(located at Scott Air Force Base) distribution server every 3 minutes. Spiral 1 also received these same feeds.
- Cloud images from the National Oceanographic and Aeronautic Administration (NOAA) Aviation Weather Center (AWC) every 30 minutes. Spiral 1 also received the same feed.
- Significant Meteorological Events (SIGMETs) from NOAA AWC every 30 minutes. Spiral 1 also received the same feed.
- Satellite derived winds from Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin every 3 hours. Spiral 1 also received the same feed.
- Digital Aeronautical Flight Information File (DAFIF) received from the National Geo-spatial Agency (NGA) every 28 days. Spiral 1 also received the same feed.

Additional Information Fusion Capability

Additional 'layers' were added to enable users to rapidly fuse relevant information to enable enhanced support for existing work and new work requirements due to organizational and duty position changes discussed in Chapter 1.3. The additional layers are:

- Tropical storm track path history and projection for currently active storms
- 15 Operational Weather Squadron annotated weather forecast charts – imported from the OPS II system
- Exclusion zones
- Air routes
- Navigational aids
- Flight path waypoints
- Flight Information Regions
- Countries – indicates country name when mouse hovers over country
- Cloud 'looping' option added to clouds layer images to show recent cloud movement history

Additional Alerting Capabilities

- Exclusion zones – user definable regions which can be selected as alert triggers if intersected by a flight path
- SIGMETs – can be selected to provide cautionary ('yellow') alerts if forecast region intersects a flight path
- Forecasts – can be selected to provide cautionary ('yellow') alerts if forecast region intersects a flight path

User Interface Display and Control Changes

The changes that distinguish the WCSS-GWM Spiral 2 capability from the WCSS-GWM Spiral 1 can be grouped by changes to the sortie palette capability consist of changes to the Sortie Palette and changes to the Mission Detail panel

Changes to the Sortie Palette

- Additional mission-related information filtering and ordering functions – Includes the ability to reorder the sorties list, filter the sorties to be displayed, monitor airfield and route conditions by sortie, and monitor alerts by sortie.
- Addition of Operational Risk Management (ORM) information for each mission. ORM values are color-coded (red, yellow, green, gray) and mouse hover text pop-up provides rationale for ORM values assigned.
- Removal of 'eyeball' design element to distinguish flight managed missions from non-flight managed missions. The capability to sort by flight managed and other sorting alternatives is provided by the filtering and ordering capability discussed above and negated the necessity of the 'eyeball' cueing.
- Enhanced alert management capability to enable users to investigate, acknowledge, and cancel alerts
- Addition of 'alert' menu to enable management of existing and additional alerting capabilities
- Additional summary information for each sortie, including mission type identifier, flight manager identifier and sortie phase status information relative to specific elements of the planning through execution continuum

Changes to the Mission Detail Display

- The ability to display the additional layers at the data frequency rates indicated in the 'Data source and rate update changes' and 'Additional fusion capability' sections above.
- Reconfiguration and relocation of the satellite derived winds and ACARS altitude filtering selector and indicator
- Removal of the mouse mode selection as 'radio' style controls
- Redesign and consolidation of the data currency cues
- Addition of 'layer' menus to facilitate minimization of requirements for layer display scrolling necessary due to the increasing number of layers added to the second spiral
- Multi-user Agent Management Tool (AMT) design that enables users to either retain the scribed agent watch area within a single client or allow it to be made available to other user clients
- The ability to display automated aircraft position reports invoked by highlighting the flight path of the desired sorties
- The ability to isolate a given flight path, temporarily hiding all others
- Three screen views – 'standard', 'compact' and 'minimal' that display varying portions of the mission detail display depending on use and user preferences. For example, the minimal display displays no controls. It is intended for use when displaying on a wall, for example, where controls are unnecessary and better use available display space to display more of the geo-spatial view.
- The ability to save and load user display customizations to minimize configuration time for new user sessions
- The ability to save the map display as a .gif or .jpg image

Software architecture changes

Changes were made to the underlying software architecture to support a larger number of users and information sharing among users via the Agent Management Tool functionality.

1.9 Glossary

ACARS – Acronym for 'Aircraft Communications and Reporting System'

ACFP - Acronym for 'Advanced Computer Flight Planner'. The label for a software application used by the flight planning shop to generate route specifications for incorporation into a mission's planning record. The ACFP system automatically generates a specification for fuel-optimized routing between two airfields (i.e., for a given 'city-pair').

ACT - Acronym for 'Automated Clearance Tool'. The ACT is the prototype DIP support application developed in a parallel project during FY03 by BBN Technologies.

AFWA - Air Force Weather Agency

AIREP – Acronym for 'Air Report' from an aircraft.

AMC - Air Mobility Command

AR - Aerial refueling.

ATC - Air traffic control.

Back Office - The main work area allocated to the 15th OWS within AMC / TACC. This is a separate office space within which the majority of on-duty WX staff work during their shifts. This is the focal site for WX staff members' generation of continuous regional forecasts, shift briefings, weather data monitoring, and handling calls from active missions and other parties.

Chartmaker - The label denoting the 'graphics guy' - i.e., the junior level back office staffer responsible for monitoring incoming WX data and generating the forecast charts.

City-Pair - The dyad of departure and arrival airfields used as the basis for generating an ACFP route specification.

DAFIF - Acronym for 'Digital Aeronautical Flight Information File'. The set of flight-related information used as the realtime reference for flight conditions and constraints.

DAP - Acronym for "Diplomatic Automation Program" - the software application providing the 'Logbook' used by all TACC staffers to accrete documentation relating to a given mission.

DIP - Acronym for 'diplomatic clearance(s)'.

DIP Summary Palette - A WCSS concept generated during GAMAT Phase II to provide rapid situation awareness on the existing DIP data associated with a given sortie.

Diplomatic Clearance - The formal credential according permission from a foreign nation to enter and transit its airspace.

Electronic Mission Folder - The name of an envisioned IT application which would provide all units within AMC / TACC with a commonly-accessible structured record for each mission being planned and followed.

EMF - Acronym for Electronic Mission Folder.

ETA - Acronym for 'Estimated Time of Arrival'.

ETD - Acronym for 'Estimated Time of Departure'.

F2 Database - The computerized repository for storing previously-delineated ACFP route specifications for future reference and / or reuse. The F2 database is maintained by the flight planning shop, and the level of effort necessary for this maintenance has grown to be worthy of a dedicated position.

F2 Route - A label for a previously specified or 'canned' route specification stored for future reference and / or reuse in the F2 database.

FalconView - A graphic mapping application used in support of mission, planning and execution. FalconView is a GOTS product originally developed by USAF in conjunction with partners.

FCG - Acronym for Foreign Clearance Guide.

FIR - Acronym for Flight Information Region. A FIR is essentially a geospatially-delineated area (region) correlated with a governing authority (e.g., for air traffic control). FIR boundaries generally do not correlate 1-to-1 with political boundaries or other area delimiters.

FIR Boundary - The boundary circumscribing a given Flight Information Region. FIR boundaries are important constructs in flight planning because permissions and authority (e.g., for ATC) begin and end at FIR boundaries.

Flight Planning Palette - A WCSS concept developed during the IFM project (2000 - 2001) and presented to TACC staff in spring 2001. This palette incorporated representations for stepwise FM planning procedure (to provide a 'checklist'), a text subwindow serving as a general work area, and miscellaneous data and alert features. The Flight Planning Palette was conceived as a modular 'clipboard' to be employed in doing flight planning and assembling crew papers. TACC later developed this concept into a tool known as the Sortie Manager.

Flight Visualization Tool - The label used during FY02 and FY03 GAMAT efforts to denote a generic visualization application focusing on flight routing elements. Multiple versions of this tool were presented and discussed during our FY03 presentations.

FM - Acronym for flight manager.

FNMOC - Acronym for 'Fleet Numerical Oceanography Center'.

Foreign Clearance Guide - The primary reference resource on diplomatic clearances, and the main reference resource used by the DIP shop. This is available in the form of hardcopy manuals physically kept in the DIP shop work area.

FP - Acronym for flight planner.

FPP - Acronym for Flight Planning Palette.

Front Office - the label for the single workstation in the integrated flight management "swimming pool" area where one or two WX staff members work in closer collaboration with flight managers (FM's) to plan and monitor flights.

FSG - Acronym for Federated Software Group. FSG was the primary developer for the Integrated Management Tool (IMT) software addressed in the IFM project. They are also the prime contractors for developing TACC's next-generation GDSS-2 system.

FVT - Acronym for Flight Visualization Tool

G2 - A colloquial shorthand acronym sometimes used around AMC to refer to GDSS-2.

GAMAT - Global Air Mobility Advanced Technologies. GAMAT occurs as both (a) the title of the program under which the work reported here was conducted and (b) an occasional label for the weather visualization applications (WCSS-GWM; WMT) the GAMAT project had developed and demonstrated during FY02 and FY03.

GDSS - Global Decision Support System. The primary repository for mission / sortie information from the point of completion of mission planning through the execution phase.

GDSS -2 - Global Decision Support System 2. The next-generation version of GDSS, currently under development by FSG. Sometimes referred to as 'G2'.

GWM - an acronym for 'Global Weather Management'. This label was occasionally used to refer to the Weather Management Tool (WMT) artifact prototyped during FY02.

WCSS-GWM - an acronym for 'Work-Centered Support System for Global Weather Management'. This label was used to refer to the Weather Management Tool (WMT) artifact prototyped during the FY03 GAMAT effort.

HISA - Human Interaction with Software Agents. This was an AFRL/HES project conducted from 1999 through 2000, aimed at demonstrating the application of intelligent software agent technologies to traditional 'shop-based' AMC/TACC flight planning operations.

ICAO - 1. International Civil Aeronautics Organization. A regulatory organization overseeing civil aviation issues worldwide. 2. A shorthand label for the official ICAO code name for a given airfield.

IFM - Integrated Flight Management. This is (a) a formal title for the dispatcher model of flight planning / following being implemented as a component of AMC's Mobility 2000 (M2K) program and (b) a general label for a mode of operations in which TACC staff serve as "dispatchers" and/or "virtual crew members" in supporting air crews.

IMT - Integrated Management Tool. This is a data integration application developed by Federated Software Group (FSG) and deployed as the primary flight planning and following support portal in the "swimming pool" within TACC.

IMT Dashboard - The central interface component of the Integrated Management Tool (IMT), consisting of a large tabular display upon which summary mission data is presented.

JMPS - Joint Mission Planning System. The joint operations planning application (or, more accurately, suite of applications) toward which DOD is migrating. The system with which our AMC-based WCSS will probably be required to interoperate if not integrate.

Lead Time - The amount of time required prior to a stated deadline for processing a DIP (diplomatic clearance) request.

Lead Time Generator / Lead Time Calculator - Two informal labels used during FY03 to denote the lead time notification / tracking capability incorporated in the ACT application being developed in parallel by BBN Technologies.

Logbook - A recently-emergent information systems application in AMC / TACC which provides personnel with a mutually-accessible repository for notes, documents, and other data on missions. The Logbook provides a location where textual data on a mission can be accreted and retrieved. The software application affording the Logbook capabilities to TACC is 'DAP'.

LUI - Acronym for 'Local User Interface'. The LUI can be described as a dedicated mini-application permitting TACC users to 'remotely' access data resources not directly accessible from their desktops. For example, the LUI provided flight managers (FM's) with a portal through which they could access ACFP.

MAR - Acronym for Mission Area Representative.

Mission Area Representative - An emerging concept for a TACC task or role which serves as the liaison between planning and execution by monitoring mission 96 hours prior through mission completion. The vision is that Mission Area Representatives are planners that would take over and follow a mission beginning at 24 hours prior to launch. As of FY03 - FY04, the concept of MAR has changed from the WX-specific version we first encountered in our GAMAT FY02 work.

Mission Forecaster - The label denoting the front office WX staffer.

MOG - Acronym for 'maximum on ground' - the term for the maximum number of aircraft that can feasibly be on-ground at a given airfield at a given time.

MOG Master - A label for a position / role that has emerged in the execution cell at TACC. The MOG Master essentially works to maintain situation awareness over mission constraints and events starting shortly before launch and continuing through execution. The title notwithstanding, the MOG Master's responsibilities are not limited to MOG issues.

MOG Viewer - A label sometimes given to the Port Viewer tool (originated in the HISA project) and/or its multiple evolutionary descendants.

NATS - Acronym for 'North Atlantic Track System'.

Notice to Airmen (NOTAM) - An announcement issued by an airfield or other authority to notify the aviation community of news, updates, changes, restrictions, etc., concerning access to and operations of a given airfield.

OPS II - Acronym for 'Operational Weather Squadron Production System, Phase II'.

ORM - Acronym for 'Operational Risk Management'.

OWS - Acronym for 'Operational Risk Management'.

PIREP - Acronym for 'Pilot Report' from an aircraft.

ROO - Acronym for 'Route Orientation Officer'.

SA - Acronym for 'situation awareness'.

Shift Status Display - The name given the original WCSS concept developed during the IFM project (2000 - 2001) representing a compact highest-level overview over the pending workstream. The basic form was that of a vertically-ordered set of tabs, each of which identified a corresponding mission / sortie, provided minimal ID info on that sorties (arrival / departure ICAO's), and a summary alert indicator to cue the user on that sortie's status. This concept's first prototype implementation was as an auxiliary feature of the WCSS-GWM under the name 'Sortie Palette'.

Sortie Manager - Name for a flight planning tool originally proposed under the title 'Flight Planning Palette' at the conclusion of the IFM project (Spring 2001). This concept was carried forward by the Flight Managers and developed locally into an actual application.

Sortie Palette - The label for the first interactive demo prototype of the IFM project's concept of a 'Shift Status Display', implemented as an auxiliary feature associated with the WCSS-GWM.

Supervisor - The local label for the 'lead' - the senior level back office WX staffer with management / work tracking / threat assessment oversight responsibilities.

TACC - Tanker Airlift Control Center - the primary transport flight operations component of Air Mobility Command (AMC).

Two-Level (F2) Database - A label for a concept developed by our GAMAT team during FY03, denoting a route repository analogous to the current F2 database within which users could index and address routes in terms of two 'levels': (a) in terms of endpoints (city-pairs) and (b) in terms of subsidiary segments of the route linking those endpoints.

WCSS - Acronym for 'work-centered support system'.

Weather Management Tool (WMT) - one of many labels used for the agent-based weather visualization tool this project has developed and demonstrated. This tool has also been referred to as the "GAMAT prototype and the WCSS-GWM".

WX - Acronym for "weather".

WXM - Refers to TACC/WXM office, which is the Weather Desk of the 15th Operational Weather Squadron.

XOCZ - Refers to TACC/XOCZ office, which is the International Flight Plans and Diplomatic Clearances Office.

XOCZD - Refers to the TACC/XOCZD office, which is the Diplomatic Clearance Division of XOCZ.

XOCZF - Refers to the TACC/XOCZF office, which is the Flight Planning Division of XOCZ.

Appendix A: Illustrative Survey of Nomenclature Used for Flight / Route Elements

The first research step in evaluating prospects for a coherent ontology or schema for categorizing flight route elements is to survey what such elements are currently defined and recognized in practice. The primary authority on U.S. aviation terminology is the FAA. This Appendix provides an overview of the diverse terms in current use for denoting and describing geospatially-delineated flight and route elements. The terms below were collected using the FAA's CATS reference database. Multiple searches were performed against the CATS online database using keywords such as *airway*, *route*, *corridor*, *segment*, *region*, *waypoint*, *track*, *path*, *flyway*, *sector*, *FIR*, *airspace*, *area*, and *zone*.

The terms listed below are not presumed to be a comprehensive enumeration of FAA-recognized route element nomenclature. However, they are sufficient to illustrate the range and categories of nomenclature in current usage. The terms are sometimes subject to differential definitions, depending on which of multiple terminology sets they appear in. The listings below are tagged to indicate which of these terminology sets include the given term and/or definition. For example, 'ATC Glossary' denotes the FAA's own Air Traffic Control Glossary; 'ICAO' denotes terms drawn from the nomenclature of the International Civilian Aviation Organization, etc.

ADIZ (ATC Glossary). (See AIR DEFENSE IDENTIFICATION ZONE.)

AERODROME (ATC Glossary). A defined AREA on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure, and movement of aircraft.

AERODROME TRAFFIC CIRCUIT [ICAO] (ATC Glossary). The specified PATH to be flown by aircraft operating in the vicinity of an aerodrome.

AIR DEFENSE IDENTIFICATION ZONE (ATC Glossary). Domestic Air Defense Identification Zone. Coastal Air Defense Identification Zone. An ADIZ over the coastal waters of the United States.

AIRPORT ADVISORY AREA (ATC Glossary). The AREA within ten miles of an airport without a control tower or where the tower is not in operation, and on which a Flight Service Station is located. (See LOCAL AIRPORT ADVISORY.) (Refer to AIM.)

AIRPORT (ATC Glossary). An AREA on land or water that is used or intended to be used for the landing and takeoff of aircraft and includes its buildings and facilities, if any.

AIRWAY [ICAO] (ATC Glossary). A control area or portion thereof established in the form of corridor equipped with radio navigational aids.

AIRWAY (ATC Glossary). A Class E airspace area established in the form of a corridor, the centerline of which is defined by radio navigational aids. (See FEDERAL AIRWAYS.) (Refer to FAR Part 71.) (Refer to AIM.)

AIRWAY BEACON (ATC Glossary). Used to mark airway SEGMENTS in remote mountain areas. The light flashes Morse code to identify the beacon site. (Refer to AIM.)

ALERT AREA (ATC Glossary). (See SPECIAL USE AIRSPACE.)

ARRIVAL SECTOR (ATC Glossary). An operational control SECTOR containing one or more meter fixes.

ALTERNATE AERODROME [ICAO] (ATC Glossary). An aerodrome to which an aircraft may proceed when it becomes either impossible or inadvisable to proceed to or to land at the aerodrome of intended landing. Note: The aerodrome from which a flight departs may also be an en-ROUTE or a destination alternate aerodrome for the flight.

ARC (ATC Glossary). The TRACK over the ground of an aircraft flying at a constant distance from a navigational aid by reference to distance measuring equipment (DME).

ATC ASSIGNED AIRSPACE (ATC Glossary). AIRSPACE of defined vertical/lateral limits, assigned by ATC, for the purpose of providing air traffic segregation between the specified activities being conducted within the assigned AIRSPACE and other IFR air traffic. (See SPECIAL USE AIRSPACE.)

ATS Route [ICAO] (ATC Glossary). A specified route designed for channeling the flow of traffic as necessary for the provision of air traffic services. Note: The term "ATS Route" is used to mean variously, AIRWAY, advisory route, controlled or uncontrolled route, arrival or departure, etc.

BLIND SPOT (ATC Glossary). An AREA from which radio transmissions and/or radar echoes cannot be received. The term is also used to describe portions of the airport not visible from the control tower.

BLIND ZONE (ATC Glossary). (See BLIND SPOT.)

CADIZ (AFTechnet). CANADIAN AIR DEFENSE IDENTIFICATION ZONE

CENTER'S AREA (ATC Glossary). The specified airspace within which an air ROUTE traffic control center (ARTCC) provides air traffic control and advisory service. (See AIR ROUTE TRAFFIC CONTROL CENTER.) (Refer to AIM.)

CHARTED VFR FLYWAYS (ATC Glossary). Charted VFR Flyways are flight PATHs recommended for use to bypass areas heavily traversed by large turbine-powered aircraft. Pilot compliance with recommended flyways and associated altitudes is strictly voluntary. VFR Flyway Planning charts are published on the back of existing VFR Terminal Area charts.

CLASS A AIRSPACE (ATC Glossary). (SEE CONTROLLED AIRSPACE)

CLASS B AIRSPACE (ATC Glossary). (SEE CONTROLLED AIRSPACE)

CLASS C AIRSPACE (ATC Glossary). (SEE CONTROLLED AIRSPACE)

CLASS D AIRSPACE (ATC Glossary). (SEE CONTROLLED AIRSPACE)

CLASS E AIRSPACE (ATC Glossary). (SEE CONTROLLED AIRSPACE)

CLASS G AIRSPACE (ATC Glossary). That AIRSPACE not designated as Class A, B, C, D or E.

CLEARWAY (ATC Glossary). An AREA beyond the takeoff runway under the control of airport authorities within which terrain or fixed obstacles may not extend above specified limits. These AREAs may be required for certain turbine-powered operations and the size and upward slope of the clearway will differ depending on when the aircraft was certificated. (Refer to FAR Part 1.)

COASTAL FIX (ATC Glossary). A navigation aid or intersection where an aircraft transitions between the domestic ROUTE structure and the oceanic ROUTE structure.

COMMON POINT (ATC Glossary). A significant point over which two or more aircraft will report passing or have reported passing before proceeding on the same or diverging TRACKs. To establish/maintain longitudinal separation, a controller may determine a common point not originally in the aircraft's flight plan and then clear the aircraft to fly over the point. (See SIGNIFICANT POINT.)

COMMON ROUTE (ATC Glossary). That SEGMENT of a North American Route between the inland navigation facility and the coastal fix.

COMPOSITE ROUTE SYSTEM (ATC Glossary). An organized oceanic ROUTE structure, incorporating reduced lateral spacing between ROUTEs, in which composite separation is authorized.

COMPULSORY REPORTING POINTS (ATC Glossary). Reporting points which must be reported to ATC. They are designated on aeronautical charts by solid triangles or filed in a flight plan as fixes selected to define direct ROUTEs. Pilots should discontinue position reporting over compulsory reporting points when informed by ATC that their aircraft is in "radar contact."

CONTROL AREA [ICAO] (ATC Glossary). A controlled AIRSPACE extending upwards from a specified limit above the earth.

CONTROL SECTOR (ATC Glossary). An airspace area of defined horizontal and vertical dimensions for which a controller or group of controllers has air traffic control responsibility, normally within an air ROUTE traffic control center or an approach control facility. Sectors are established based on predominant traffic flows, altitude strata, and controller workload. Pilot-communications during operations within a sector are normally maintained on discrete frequencies assigned to the sector.

CONTROLLED AIRSPACE [ICAO] (ATC Glossary). An AIRSPACE of defined dimensions within which air traffic control service is provided to IFR flights and to VFR flights in accordance with the AIRSPACE classification. (Note: Controlled AIRSPACE is a generic term which covers ATS AIRSPACE Classes A, B, C, D, and E.)

CONTROLLED AIRSPACE (ATC Glossary). An AIRSPACE of defined dimensions within which air traffic control service is provided to IFR flights and to VFR flights in accordance with the AIRSPACE classification. Controlled AIRSPACE is a generic term that covers Class A, Class B, Class C, Class D, and Class E AIRSPACE. 5. CLASS E Generally, if the AIRSPACE is not Class A, Class B, Class C, or Class D, and it is controlled AIRSPACE, it is Class E AIRSPACE.

COURSE (ATC Glossary). The intended direction of flight in the horizontal plane measured in degrees from north. The ILS localizer signal pattern usually specified as the front course or the back course. The intended track along a straight, curved, or SEGMENTED MLS path.

DANGER AREA [ICAO] (ATC Glossary). An AIRSPACE of defined dimensions within which activities dangerous to the flight of aircraft may exist at specified times. Note: The term "Danger Area" is not used in reference to areas within the United States or any of its possessions or territories.

DESIRED TRACK (ATC Glossary). The planned or intended track between two WAYPOINTS. It is measured in degrees from either magnetic or true north. The instantaneous angle may change from point to point along the great circle track between WAYPOINTS.

DEWIS (AFTechnet). DISTANT EARLY WARNING ZONE

DEWIZ (TAG). Distance Early Warning Identification ZONE

DIRECT (ATC Glossary). Straight line flight between two navigational aids, fixes, points, or any combination thereof. When used by pilots in describing off-airway routes, points defining direct route SEGMENTS become compulsory reporting points unless the aircraft is under radar contact.

DIVERSE VECTOR AREA (ATC Glossary). In a radar environment, that area in which a prescribed departure ROUTE is not required as the only suitable ROUTE to avoid obstacles. The area in which random radar vectors below the MVA/MIA, established in accordance with the TERPS criteria for diverse departures, obstacles and terrain avoidance, may be issued to departing aircraft.

DOMESTIC AIRSPACE (ATC Glossary). AIRSPACE which overlies the continental land mass of the United States plus Hawaii and U.S. possessions. Domestic AIRSPACE extends to 12 miles offshore.

DSUA (TAG). Dynamic Special - Use AIRSPACE

DSUA (AFTechnet). Dynamic Special Use AIRSPACE

DVA (ATC Glossary). (See DIVERSE VECTOR AREA.)

FEEDER FIX (ATC Glossary). The fix depicted on Instrument Approach Procedure Charts which establishes the starting point of the feeder ROUTE.

FEEDER ROUTE (ATC Glossary). A ROUTE depicted on instrument approach procedure charts to designate ROUTEs for aircraft to proceed from the en ROUTE structure to the initial approach fix (IAF). (See INSTRUMENT APPROACH PROCEDURE.)

FINAL APPROACH COURSE (ATC Glossary). A bearing/radial/TRACK of an instrument approach leading to a runway or an extended runway centerline all without regard to distance.

FINAL APPROACH FIX (ATC Glossary). The fix from which the final approach (IFR) to an airport is executed and which identifies the beginning of the final approach SEGMENT. It is designated on Government charts by the Maltese Cross symbol for nonprecision approaches and the lightning bolt symbol for precision approaches; or when ATC directs a lower-than-published glideslope/path intercept altitude, it is the resultant actual point of the glideslope/path intercept. (See SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE.)

FINAL APPROACH POINT (ATC Glossary). The point, applicable only to a nonprecision approach with no depicted FAF (such as an on airport VOR), where the aircraft is established inbound on the final approach course from the procedure turn and where the final approach descent may be commenced. The FAP serves as the FAF and identifies the beginning of the final approach SEGMENT. (See SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE.)

FINAL APPROACH SEGMENT [ICAO] (ATC Glossary). That SEGMENT of an instrument approach procedure in which alignment and descent for landing are accomplished.

FINAL APPROACH SEGMENT (ATC Glossary). (See SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE.)

FINAL APPROACH-IFR (ATC Glossary). The flight path of an aircraft which is inbound to an airport on a final instrument approach course, beginning at the final approach fix or point and extending to the airport or the point where a circle-to-land maneuver or a missed approach is executed. (See SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE.) (See ICAO term FINAL APPROACH.)

FIR (ATC Glossary). (See FLIGHT INFORMATION REGION.)

FLIGHT INFORMATION REGION (ATC Glossary). An AIRSPACE of defined dimensions within which Flight Information Service and Alerting Service are provided. A service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights. A service provided to notify appropriate organizations regarding aircraft in need of search and rescue aid and to assist such organizations as required.

FLIGHT PATH (ATC Glossary). A line, course, or TRACK along which an aircraft is flying or intended to be flown. (See TRACK.) (See COURSE.)

FLIGHT PLAN AREA (ATC Glossary). The geographical AREA assigned by regional air traffic divisions to a flight service station for the purpose of search and rescue for VFR aircraft, issuance of NOTAMs, pilot briefing, in-flight services, broadcast, emergency services, flight data processing, international operations, and aviation weather services. Three letter identifiers are assigned to every flight service station and are annotated in AFD's and FAA Order 7350.6, LOCATION IDENTIFIERS, as tie-in-facilities. (See FAST FILE.)

FLY-BY WAYPOINT (ATC Glossary). A fly-by waypoint requires the use of turn anticipation to avoid overshoot of the next flight SEGMENT.

FLY-OVER WAYPOINT (ATC Glossary). A fly-over waypoint precludes any turn until the waypoint is overflown and is followed by an intercept maneuver of the next flight SEGMENT.

GAOC (ZAB Acronym List). GEOGRAPHIC AREA OF CONCERN

HIWAS AREA (ATC Glossary). (See HAZARDOUS INFLIGHT WEATHER ADVISORY SERVICE.)

HIWAS BROADCAST AREA (ATC Glossary). A geographical AREA of responsibility including one or more HIWAS outlet AREAs assigned to an AFSS/FSS for hazardous weather advisory broadcasting.

HIWAS OUTLET AREA (ATC Glossary). An AREA defined as a 150 NM radius of a HIWAS outlet, expanded as necessary to provide coverage.

IFR MILITARY TRAINING ROUTES (IR) (ATC Glossary). ROUTEs used by the Department of Defense and associated Reserve and Air Guard units for the purpose of conducting low-altitude navigation and tactical training in both IFR and VFR weather conditions below 10,000 feet MSL at airspeeds in excess of 250 knots IAS.

INITIAL APPROACH FIX (ATC Glossary). The fixes depicted on instrument approach procedure charts that identify the beginning of the initial approach SEGMENT(s). (See FIX.) (See SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE.)

INITIAL APPROACH SEGMENT [ICAO] (ATC Glossary). That SEGMENT of an instrument approach procedure between the initial approach fix and the intermediate approach fix or, where applicable, the final approach fix or point.

INITIAL APPROACH SEGMENT (ATC Glossary). (See SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE.)

INTERMEDIATE APPROACH SEGMENT [ICAO] (ATC Glossary). That SEGMENT of an instrument approach procedure between either the intermediate approach fix and the final approach fix or point, or between the end of a reversal, race track or dead reckoning track procedure and the final approach fix or point, as appropriate.

INTERMEDIATE FIX (ATC Glossary). The fix that identifies the beginning of the intermediate approach SEGMENT of an instrument approach procedure. The fix is not normally identified on the instrument approach chart as an intermediate fix (IF). (See SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE.)

IF/IAWP (ATC Glossary). Intermediate Fix/Initial Approach WAYPOINT. The WAYPOINT where the final approach course of a T approach meets the crossbar of the T. When designated (in conjunction with a TAA) this WAYPOINT will be used as an IAWP when approaching the airport from certain directions, and as an IFWP when beginning the approach from another IAWP.

JET ROUTE (ATC Glossary). A ROUTE designed to serve aircraft operations from 18,000 feet MSL up to and including flight level 450. The ROUTEs are referred to as "J" ROUTEs with numbering to identify the designated ROUTE; e.g., J105. (See Class A AIRSPACE.) (Refer to FAR Part 71.)

JOINT USE RESTRICTED AREA (ATC Glossary). (See RESTRICTED AREA.)

LANDING AREA [ICAO] (ATC Glossary). That part of a movement AREA intended for the landing or takeoff of aircraft.

LANDING AREA (ATC Glossary). Any locality either on land, water, or structures, including airports/heliports and intermediate landing fields, which is used, or intended to be used, for the landing and takeoff of aircraft whether or not facilities are provided for the shelter, servicing, or for receiving or discharging passengers or cargo. (See ICAO term LANDING AREA.)

LOW ALTITUDE AIRWAY STRUCTURE (ATC Glossary). The network of AIRWAYs serving aircraft operations up to but not including 18,000 feet MSL. (See AIRWAY.) (Refer to AIM.)

METERING FIX (ATC Glossary). A fix along an established ROUTE from over which aircraft will be metered prior to entering terminal airspace. Normally, this fix should be established at a distance from the airport which will facilitate a profile descent 10,000 feet above airport elevation [AAE] or above.

MILITARY OPERATIONS AREA (ATC Glossary). (See SPECIAL USE AIRSPACE.)

MILITARY TRAINING ROUTES (ATC Glossary). Airspace of defined vertical and lateral dimensions established for the conduct of military flight training at airspeeds in excess of 250 knots IAS. (See IFR MILITARY TRAINING ROUTES.) (See VFR MILITARY TRAINING ROUTES.)

MINIMUM NAVIGATION PERFORMANCE SPECIFICATIONS AIRS (ATC Glossary). Designated airspace in which MNPS procedures are applied between MNPS certified and equipped aircraft. Under certain conditions, non-MNPS aircraft can operate in MNPSA. However, a standard oceanic separation minimum is provided between the non-MNPS aircraft and other traffic.

MISSED APPROACH POINT (ATC Glossary). A point prescribed in each instrument approach procedure at which a missed approach procedure shall be executed if the required visual reference does not exist. (See MISSED APPROACH.) (See SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE.)

MISSED APPROACH SEGMENT (ATC Glossary). (See SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE.)

MOA (ATC Glossary). (See MILITARY OPERATIONS AREA.)

MOA (TAG). Military Operations AREA

MOVEMENT AREA [ICAO] (ATC Glossary). That part of an aerodrome to be used for the takeoff, landing and taxiing of aircraft, consisting of the maneuvering AREA and the apron(s).

MOVEMENT AREA (ATC Glossary). The runways, taxiways, and other AREAs of an airport/heliport which are utilized for taxiing/hover taxiing, air taxiing, takeoff, and landing of aircraft, exclusive of loading ramps and parking AREAs. At those airports/heliports with a tower, specific approval for entry onto the movement AREA must be obtained from ATC. (See ICAO term MOVEMENT AREA.)

NATIONAL AIRSPACE SYSTEM (ATC Glossary). The common network of U.S. AIRSPACE; air navigation facilities, equipment and services, airports or landing areas; aeronautical charts, information and services; rules, regulations and procedures, technical information, and manpower and material. Included are system components shared jointly with the military.

NATIONAL BEACON CODE ALLOCATION PLAN AIRSPACE (ATC Glossary). Airspace over United States territory located within the North American continent between Canada and Mexico, including adjacent territorial waters outward to about boundaries of oceanic control areas (CTA)/Flight Information Regions (FIR). (See FLIGHT INFORMATION REGION.)

NAVIGABLE AIRSPACE (ATC Glossary). AIRSPACE at and above the minimum flight altitudes prescribed in the FAR's including AIRSPACE needed for safe takeoff and landing. (Refer to FAR Part 91.)

NBCAP AIRSPACE (ATC Glossary). (See NATIONAL BEACON CODE ALLOCATION PLAN AIRSPACE.)

NO GYRO APPROACH (ATC Glossary). A radar approach/vector provided in case of a malfunctioning gyro-compass or directional gyro. Instead of providing the pilot with headings to be flown, the controller observes the radar TRACK and issues control instructions "turn right/left" or "stop turn" as appropriate. (Refer to AIM.)

NO TRANSGRESSION ZONE (NTZ) (ATC Glossary). The NTZ is a 2,000 foot wide ZONE, located equidistant between parallel runway final approach courses in which flight is not allowed.

NONCOMMON ROUTE/PORTION (ATC Glossary). That SEGMENT of a North American Route between the inland navigation facility and a designated North American terminal.

NONMOVEMENT AREAS (ATC Glossary). Taxiways and apron (ramp) AREAs not under the control of air traffic.

NORMAL OPERATING ZONE (NOZ) (ATC Glossary). The NOZ is the operating ZONE within which aircraft flight remains during normal independent simultaneous parallel ILS approaches.

NORTH AMERICAN ROUTE (ATC Glossary). A numerically coded route preplanned over existing airway and route systems to and from specific coastal fixes serving the North Atlantic. That SEGMENT of a North American Route between the inland navigation facility and the coastal fix. That SEGMENT of a North American Route between the inland navigation facility and a designated North American terminal.

NORTH PACIFIC (ATC Glossary). An organized ROUTE system between the Alaskan west coast and Japan.

NTZ (AFTechnet). No Transgression ZONE

OBSTACLE FREE ZONE (ATC Glossary). The runway OFZ and when applicable, the inner-approach OFZ, and the inner-transitional OFZ, comprise the OFZ. The runway OFZ is a defined volume of AIRSPACE centered above the runway. The runway OFZ extends 200 feet beyond each end of the runway.

OCA (AFTechnet). OCEANIC CONTROL AREA

OCEANIC AIRSPACE (ATC Glossary). AIRSPACE over the oceans of the world, considered international AIRSPACE, where oceanic separation and procedures per the International Civil Aviation Organization are applied. Responsibility for the provisions of air traffic control service in this AIRSPACE is delegated to various countries, based generally upon geographic proximity and the availability of the required resources.

OCEANIC PUBLISHED ROUTE (ATC Glossary). A route established in international airspace and charted or described in flight information publications, such as Route Charts, DOD Enroute Charts, Chart Supplements, NOTAM's, and TRACK Messages.

OCEANIC TRANSITION ROUTE (ATC Glossary). An ATS route established for the purpose of transitioning aircraft to/from an organized TRACK system.

OFA (TAG). Object Free AREA

OFFSHORE CONTROL AREA (ATC Glossary). That portion of airspace between the U.S. 12-mile limit and the oceanic CTA/FIR boundary within which air traffic control is exercised. These areas are established to permit the application of domestic procedures in the provision of air traffic control services. Offshore control area is generally synonymous with Federal Aviation Regulations, FAR Part 71, Subpart E, "Control Areas and Control Area Extensions."

OFZ (TAG). Obstacle Free ZONE

ORGANIZED TRACK SYSTEM (ATC Glossary). A series of ATS routes which are fixed and charted; i.e., CEP, NOPAC, or flexible and described by NOTAM; i.e., NAT TRACK MESSAGE.

ORGANIZED TRACK SYSTEM (ATC Glossary). A movable system of oceanic TRACKs that traverses the North Atlantic between Europe and North America the physical position of which is determined twice daily taking the best advantage of the winds aloft.

OUTER AREA (ATC Glossary). (associated with Class C AIRSPACE) Nonregulatory AIRSPACE surrounding designated Class C AIRSPACE airports wherein ATC provides radar vectoring and sequencing on a full-time basis for all IFR and participating VFR aircraft. The service provided in the outer area is called Class C service which includes: IFR/IFR-standard IFR separation; IFR/VFR-traffic advisories and conflict resolution; and VFR/VFR-traffic advisories and, as appropriate, safety alerts.

OUTER FIX (ATC Glossary). An adapted fix along the converted ROUTE of flight, prior to the meter fix, for which crossing times are calculated and displayed in the metering position list.

OUTER FIX (ATC Glossary). A general term used within ATC to describe fixes in the terminal area, other than the final approach fix. Aircraft are normally cleared to these fixes by an Air ROUTE Traffic Control Center or an Approach Control Facility. Aircraft are normally cleared from these fixes to the final approach fix or final approach course.

PARALLEL OFFSET ROUTE (ATC Glossary). A parallel TRACK to the left or right of the designated or established airway/route. Normally associated with Area Navigation (RNAV) operations. (See AREA NAVIGATION.)

PCA (TAG). Positive Control AIRSPACE

POLAR TRACK STRUCTURE (ATC Glossary). A system of organized routes between Iceland and Alaska which overlie Canadian MNPS Airspace.

PREFERENTIAL ROUTES (ATC Glossary). Locations having a need for these specific inbound and outbound ROUTES normally publish such ROUTES in local facility bulletins, and their use by pilots minimizes flight plan ROUTE amendments. It may be included in a Standard Instrument Departure (SID) or a Preferred IFR ROUTE. It may be included in a Standard Terminal Arrival (STAR) or a Preferred IFR ROUTE.

PREFERRED IFR ROUTES (ATC Glossary). Routes established between busier airports to increase system efficiency and capacity. Preferred IFR Routes are listed in the Airport/Facility Directory. Preferred IFR Routes are correlated with SID's and STAR's and may be defined by airways, jet routes, direct routes between NAVAID's, WAYPOINTS, NAVAID radials/DME, or any combinations thereof.

PROHIBITED AREA [ICAO] (ATC Glossary). An AIRSPACE of defined dimensions, above the land areas or territorial waters of a State, within which the flight of aircraft is prohibited.

PROHIBITED AREA (ATC Glossary). (See SPECIAL USE AIRSPACE.) (See ICAO term PROHIBITED AREA.)

PROTECTED AIRSPACE (ATC Glossary). The AIRSPACE on either side of an oceanic route/track that is equal to one-half the lateral separation minimum except where reduction of protected AIRSPACE has been authorized.

PROTECTED AIRSPACE (ATC Glossary). The airspace on either side of an oceanic route/TRACK that is equal to one-half the lateral separation minimum except where reduction of protected airspace has been authorized.

PUBLISHED ROUTE (ATC Glossary). A route for which an IFR altitude has been established and published; e.g., Federal AIRWAYS, Jet Routes, Area Navigation Routes, Specified Direct Routes.

RADAR ENVIRONMENT (ATC Glossary). An AREA in which radar service may be provided. (See ADDITIONAL SERVICES.) (See RADAR CONTACT.)

RADAR ROUTE (ATC Glossary). A flight PATH or route over which an aircraft is vectored. Navigational guidance and altitude assignments are provided by ATC. (See FLIGHT PATH.)

RANDOM ROUTE (ATC Glossary). Any ROUTE not established or charted/published or not otherwise available to all users.

RESTRICTED AREA [ICAO] (ATC Glossary). An AIRSPACE of defined dimensions, above the land areas or territorial waters of a State, within which the flight of aircraft is restricted in accordance with certain specified conditions.

RESTRICTED AREA (ATC Glossary). (See SPECIAL USE AIRSPACE.) (See ICAO term RESTRICTED AREA.)

ROUTE (ATC Glossary). A defined PATH, consisting of one or more courses in a horizontal plane, which aircraft traverse over the surface of the earth. (See JET ROUTE.) (See PUBLISHED ROUTE.)

ROUTE SEGMENT [ICAO] (ATC Glossary). A portion of a route to be flown, as defined by two consecutive significant points specified in a flight plan.

ROUTE SEGMENT (ATC Glossary). As used in Air Traffic Control, a part of a route that can be defined by two navigational fixes, two NAVAID's, or a fix and a NAVAID. (See FIX.) (See ICAO term ROUTE SEGMENT.)

RUNWAY SAFETY AREA (ATC Glossary). A defined surface surrounding the runway prepared, or suitable, for reducing the risk of damage to airplanes in the event of an undershoot, overshoot, or excursion from the runway. The dimensions of the RSA vary and can be determined by using the criteria contained within the Federal Aviation Administration, Airport Advisory Circular Number: AC 150/5300-13, Airport Design, Chapter 3. Figure 3-1 in AC 150/5300-13 depicts the RSA. Capable, under dry conditions, of supporting snow removal equipment, aircraft rescue and firefighting equipment, and the occasional.

RUNWAY (ATC Glossary). A defined rectangular AREA on a land airport prepared for the landing and takeoff run of aircraft along its length. Runways are normally numbered in relation to their magnetic direction rounded off to the nearest 10 degrees; e.g., Runway 01, Runway 25. (See PARALLEL RUNWAYS.) (See ICAO term RUNWAY.)

SEGMENTS OF AN INSTRUMENT APPROACH PROCEDURE (ATC Glossary). Initial Approach the SEGMENT between the initial approach fix and the intermediate fix or the point where the aircraft is established on the intermediate course or final approach course. Intermediate Approach the SEGMENT between the intermediate fix or point and the final approach fix. Final Approach the SEGMENT between the final approach fix or point and the runway, airport, or missed approach point.

SIGNIFICANT POINT (ATC Glossary). A point, whether a named intersection, a NAVAID, a fix derived from a NAVAID(s), or geographical coordinate expressed in degrees of latitude and longitude, which is established for the purpose of providing separation, as a reporting point, or to delineate a ROUTE of flight.

SINGLE DIRECTION ROUTES (ATC Glossary). Preferred IFR ROUTEs which are sometimes depicted on high altitude en ROUTE charts and which are normally flown in one direction only. (See PREFERRED IFR ROUTES.) (Refer to AIRPORT/FACILITY DIRECTORY.)

SPECIAL USE AIRSPACE (ATC Glossary). Alert Area Airspace which may contain a high volume of pilot training activities or an unusual type of aerial activity, neither of which is hazardous to aircraft. Controlled Firing Area Airspace wherein activities are conducted under conditions so controlled as to eliminate hazards to nonparticipating aircraft and to ensure the safety of persons and property on the ground. Prohibited Area Airspace designated under part 73 within which no person may operate an aircraft without the permission.

SPEED SEGMENTS (ATC Glossary). Portions of the arrival route between the transition point and the vertex along the optimum flight path for which speeds and altitudes are specified. There is one set of arrival speed SEGMENTS adapted from each transition point to each vertex. Each set may contain up to six SEGMENTS.

STEPDOWN FIX (ATC Glossary). A fix permitting additional descent within a SEGMENT of an instrument approach procedure by identifying a point at which a controlling obstacle has been safely overflown.

STEREO ROUTE (ATC Glossary). A routinely used ROUTE of flight established by users and ARTCC's identified by a coded name; e.g., ALPHA 2. These ROUTEs minimize flight plan handling and communications.

STOPWAY (ATC Glossary). An AREA beyond the takeoff runway no less wide than the runway and centered upon the extended centerline of the runway, able to support the airplane during an aborted takeoff, without causing structural damage to the airplane, and designated by the airport authorities for use in decelerating the airplane during an aborted takeoff.

SUA (NAS Architecture 4). Special use AIRSPACE

SUBSTITUTE ROUTE (ATC Glossary). A route assigned to pilots when any part of an AIRWAY or route is unusable because of NAVAID status. These routes consist of Routes defined by ATC as specific NAVAID radials or courses.

SURFACE AREA (ATC Glossary). The AIRSPACE contained by the lateral boundary of the Class B, C, D, or E AIRSPACE designated for an airport that begins at the surface and extends upward.

TERMINAL AREA (ATC Glossary). A general term used to describe AIRSPACE in which approach control service or airport traffic control service is provided.

TERMINAL AREA FACILITY (ATC Glossary). A facility providing air traffic control service for arriving and departing IFR, VFR, Special VFR, and on occasion en route aircraft. (See APPROACH CONTROL FACILITY.) (See TOWER.)

TERMINAL RADAR SERVICE AREA (ATC Glossary). AIRSPACE surrounding designated airports wherein ATC provides radar vectoring, sequencing, and separation on a full-time basis for all IFR and participating VFR aircraft. Service provided in a TRSA is called Stage III Service. The AIM contains an explanation of TRSA.

TOUCHDOWN [ICAO] (ATC Glossary). The point where the nominal glide PATH intercepts the runway. Note: Touchdown as defined above is only a datum and is not necessarily the actual point at which the aircraft will touch the runway.

TOUCHDOWN (ATC Glossary). The point at which an aircraft first makes contact with the landing surface. Concerning a precision radar approach (PAR), it is the point where the glide PATH intercepts the landing surface. (See ICAO term TOUCHDOWN.)

TOUCHDOWN ZONE [ICAO] (ATC Glossary). The portion of a runway, beyond the threshold, where it is intended landing aircraft first contact the runway.

TOUCHDOWN ZONE (ATC Glossary). The first 3,000 feet of the runway beginning at the threshold. The AREA is used for determination of Touchdown Zone Elevation in the development of straight-in landing minimums for instrument approaches. (See ICAO term TOUCHDOWN ZONE.)

TRACK [ICAO] (ATC Glossary). The projection on the earth's surface of the path of an aircraft, the direction of which path at any point is usually expressed in degrees from North (True, Magnetic, or Grid).

TRACK (ATC Glossary). The actual flight path of an aircraft over the surface of the earth. (See FLIGHT PATH.) (See ICAO term TRACK.)

TRANSITION (ATC Glossary). The general term that describes the change from one phase of flight or flight condition to another; e.g., transition from en route flight to the approach or transition from instrument flight to visual flight. A published procedure (SID Transition) used to connect the basic SID to one of several en route AIRWAYS/jet routes, or a published procedure (STAR Transition) used to connect one of several en route AIRWAYS/jet routes to the basic STAR. (Refer to SID/STAR Charts.)

TRANSITION POINT (ATC Glossary). A point at an adapted number of miles from the vertex at which an arrival aircraft would normally commence descent from its en route altitude. This is the first fix adapted on the arrival speed SEGMENTS.

TRANSITIONAL AIRSPACE (ATC Glossary). That portion of controlled AIRSPACE wherein aircraft change from one phase of flight or flight condition to another.

UNPUBLISHED ROUTE (ATC Glossary). A route for which no minimum altitude is published or charted for pilot use. It may include a direct route between NAVAID's, a radial, a radar vector, or a final approach course beyond the SEGMENTs of an instrument approach procedure. (See PUBLISHED ROUTE.)

VERTEX (ATC Glossary). The last fix adapted on the arrival speed SEGMENTs. Normally, it will be the outer marker of the runway in use. However, it may be the actual threshold or other suitable common point on the approach path for the particular runway configuration.

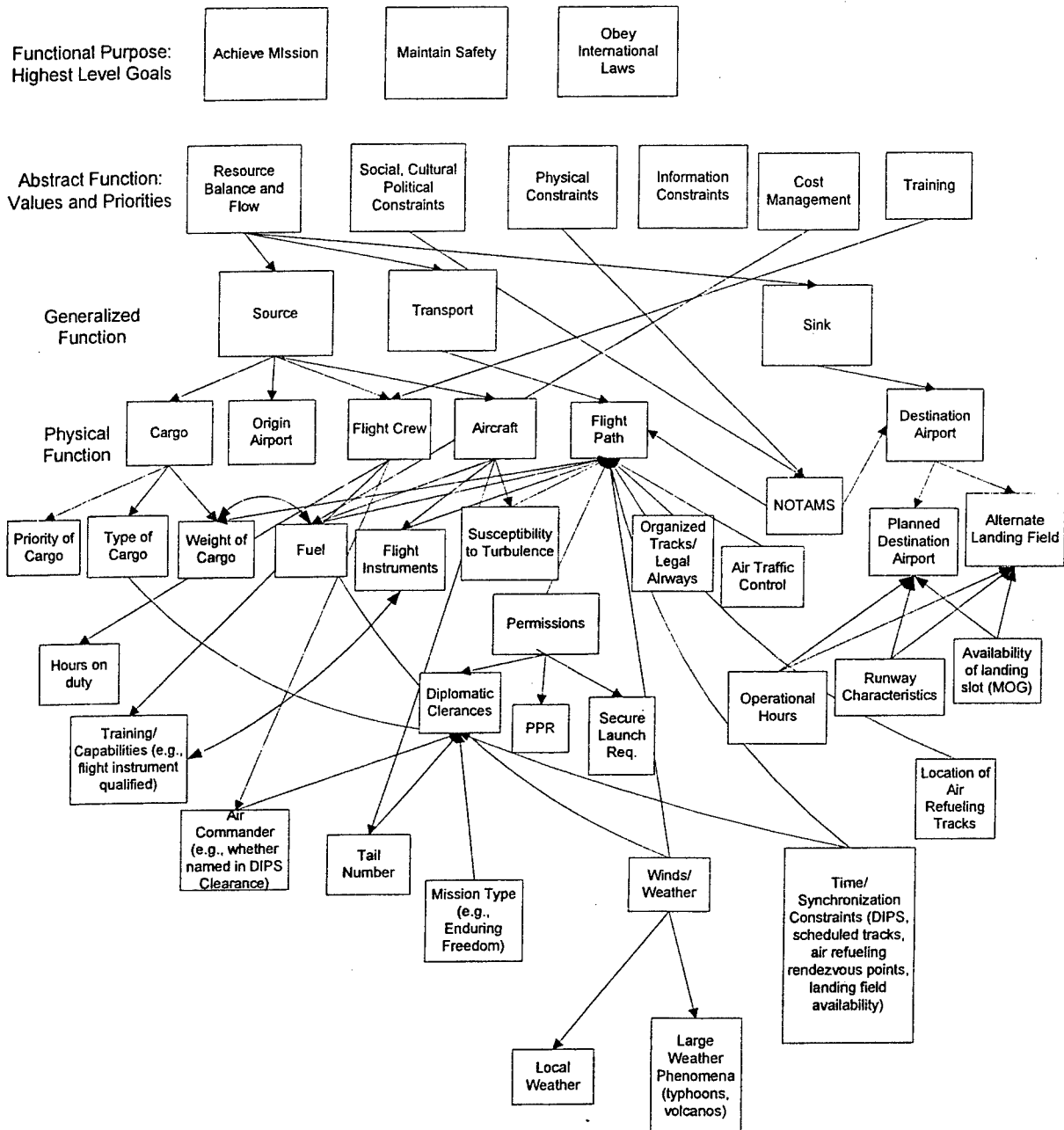
VFR MILITARY TRAINING ROUTES (ATC Glossary). ROUTEs used by the Department of Defense and associated Reserve and Air Guard units for the purpose of conducting low-altitude navigation and tactical training under VFR below 10,000 feet MSL at airspeeds in excess of 250 knots IAS.

WARNING AREA (ATC Glossary). (See SPECIAL USE AIRSPACE.)

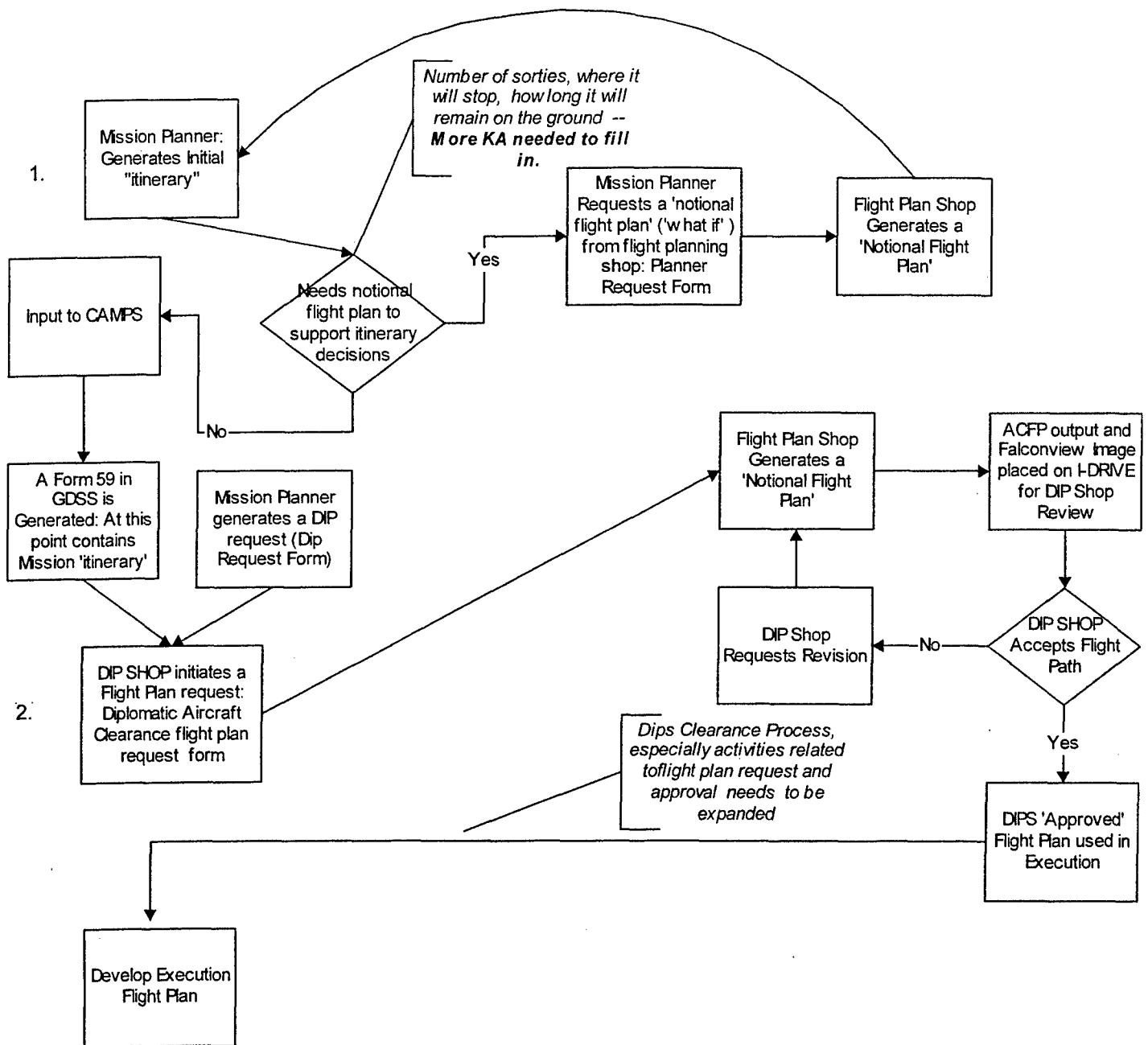
WAYPOINT (ATC Glossary). A predetermined geographical position used for route/instrument approach definition, or progress reporting purposes, that is defined relative to a VORTAC station or in terms of latitude/longitude coordinates.

Appendix B: TACC Flight Planning-related Collaborative Work and Flight Planning Work Analysis and Design Effort Analysis Aids

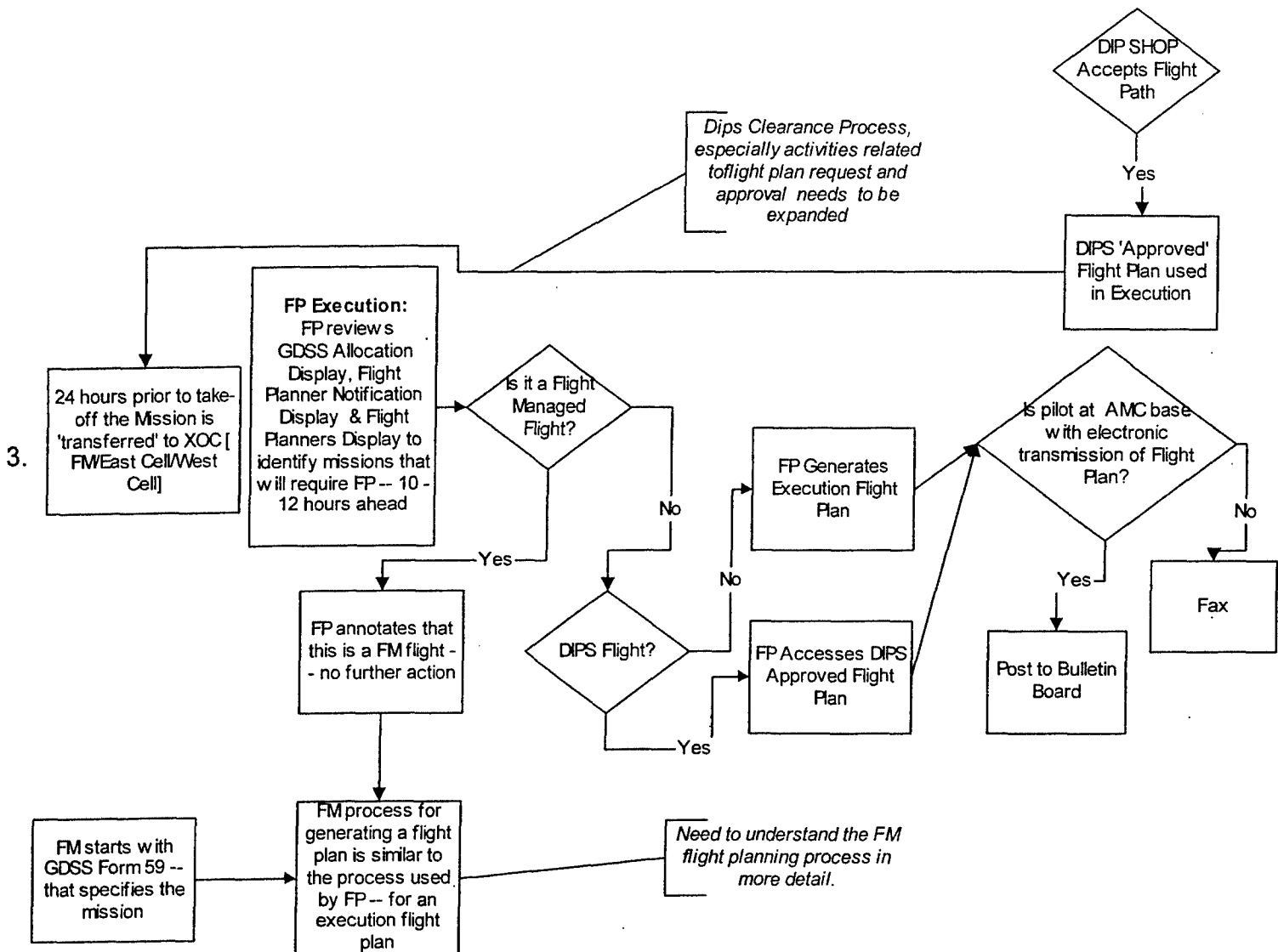
Flight Planning Work: Abstraction Hierarchy



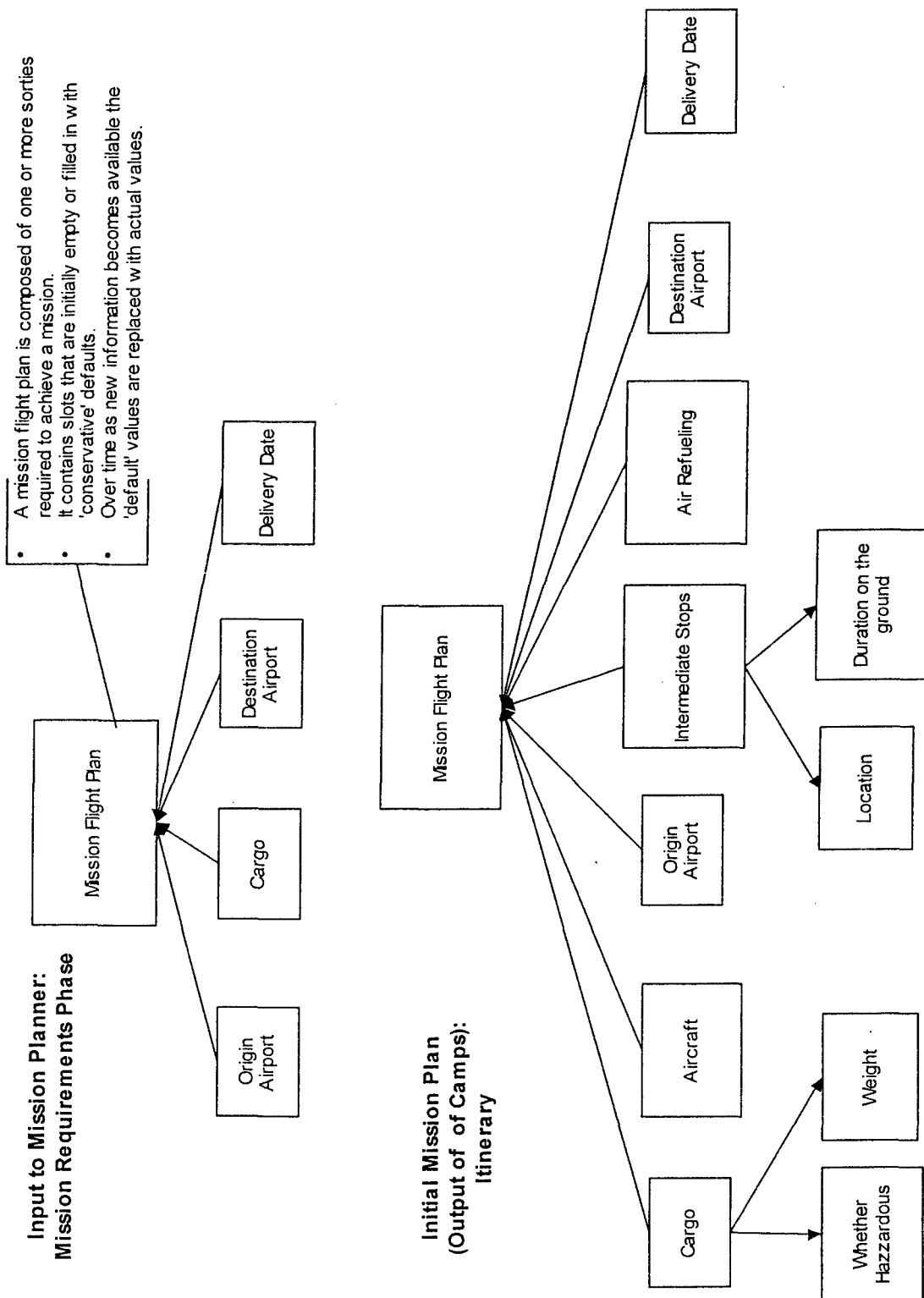
Flight Planning Work Flow: Developing a 'Notional Flight Plan'



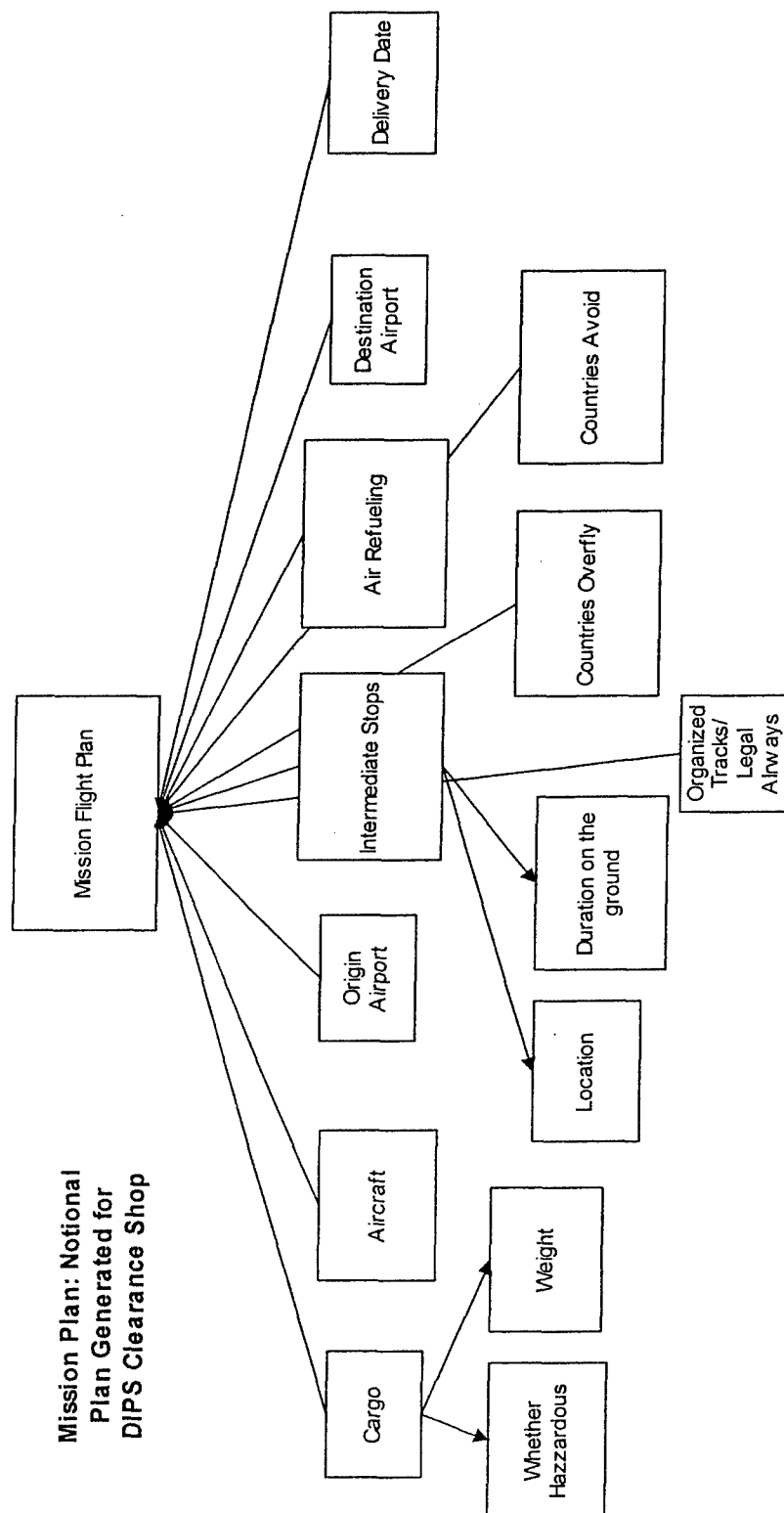
Flight Planning Work Flow: Developing an 'Execution Flight Plan'



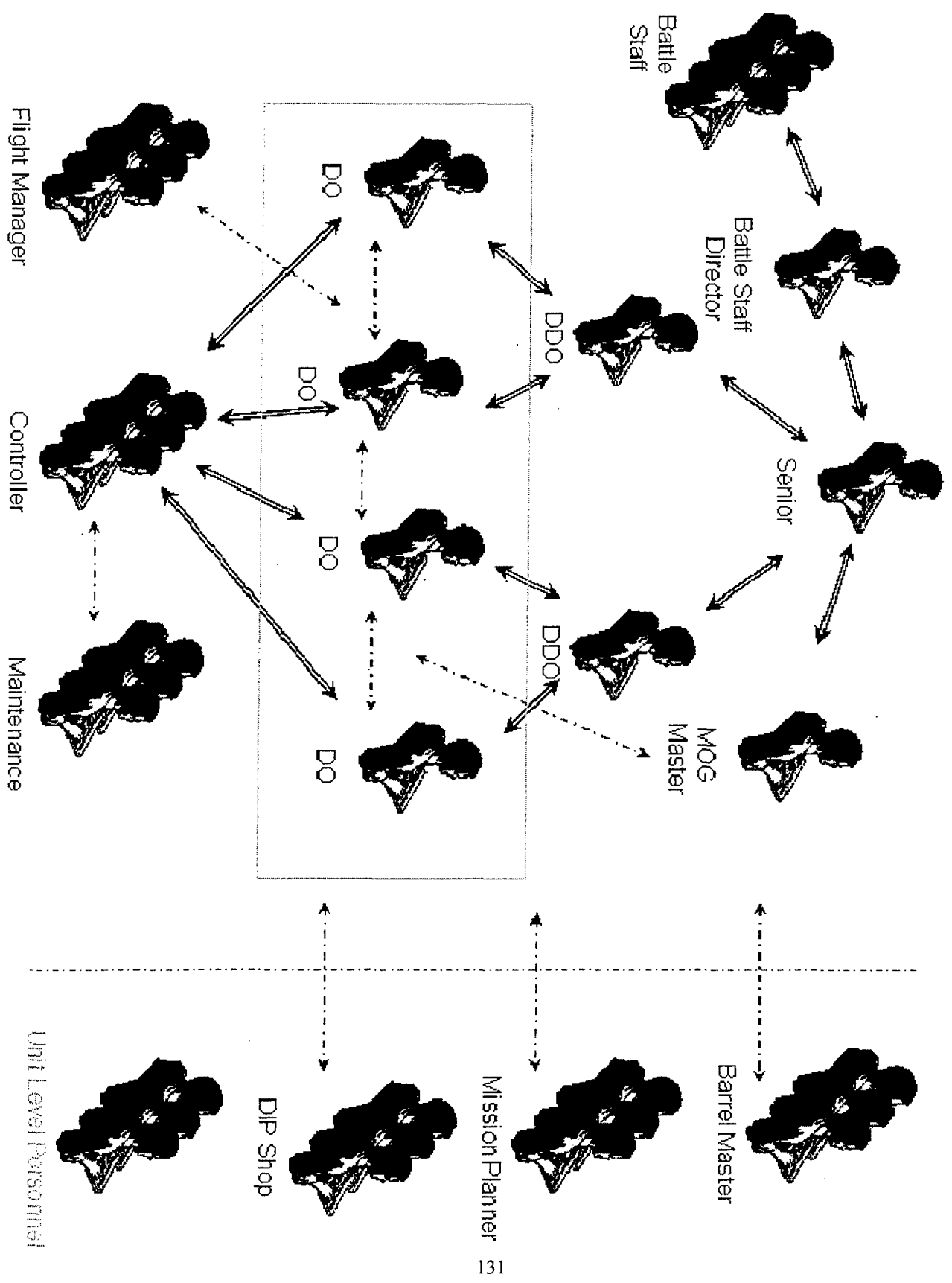
Life Cycle of a Mission: Initial Itinerary



Life Cycle of a Mission: 'Notional Plan for DIPS Shop'



Select Flight Planning-related TACC Collaboration, Coordination Relationships



Appendix C: DIP Summary Palette Concept

This Appendix documents the DIP Summary Palette - a WCSS 'viewer' concept generated and briefed during GAMAT Phase II. This concept was not developed further during the Phase II effort. To preserve a record of this concept, its features, and the rationale underlying it, this Appendix is provided.

A WCSS 'Viewer' for Summary DIP Data

In the course of the GAMAT Phase II effort we invested considerable time in examining and analyzing the relationship between the flight planning function and the DIP clearance function. The feasibility and availability of DIP clearances was often cited as a primary class of constraints on the flight planning process and the ability to replan flights as circumstances demanded. Through our knowledge acquisition and work-centered analyses we determined that:

- DIP parameters are sufficiently orderly and regular as to be represented in a structured way.
- The criticality of DIP status was sufficiently high to recommend prioritization of DIP status visualization as a component of any TACC collaborative WCSS suite.
- No capability for rapid summary display of DIP data associated with a mission was currently in place.
- Certain DIP-related decision elements (e.g., planned and feasible entry and exit timeframes) were not directly accessible and had to be computed or interpreted from what textual data could be retrieved.
- To the extent that access to DIP data is currently feasible, it is not easily available across the entire TACC team.
- Some key types of information relevant to decision making with regard to DIP prospects are not accessible at all beyond the bounds of the DIP shop (e.g., the number of blanket clearances available).
- The types of data necessary to represent DIP status were accessible and tractable enough to make a DIP 'viewer' a feasible prospect.
- A widely-accessible such DIP viewer would reduce coordination overhead for the TACC team (e.g., allowing flight planners or execution staff to directly check DIP info without placing a call to the DIP shop).
- Such a capability would help mitigate the risks of DIP factor oversight and errors during time-critical decision making processes (e.g., during the execution phase).
- A WCSS aid providing summary DIP status data associated with a given mission would be a useful work-centered innovation.

As a result, a work-oriented 'viewer' concept was generated and briefed during the latter stages of the GAMAT Phase II effort. In the sections below we shall review the features of this WCSS concept.

General Layout of the DIP Summary Palette

The DIP Summary Palette was conceived as a specialized 'viewer' - i.e., an information resource which could be readily invoked to provide summary data for a given topic or subject (i.e., DIP parameters) associated with a given mission. The concept was introduced as a 'palette' (an on-screen window with specific structure). This palette was subdivided into two basic subareas: (a) a header area for presentation of overview information; and (b) a data presentation area for display of key DIP parameters in a structured format. This general layout is illustrated in Figure D-1.

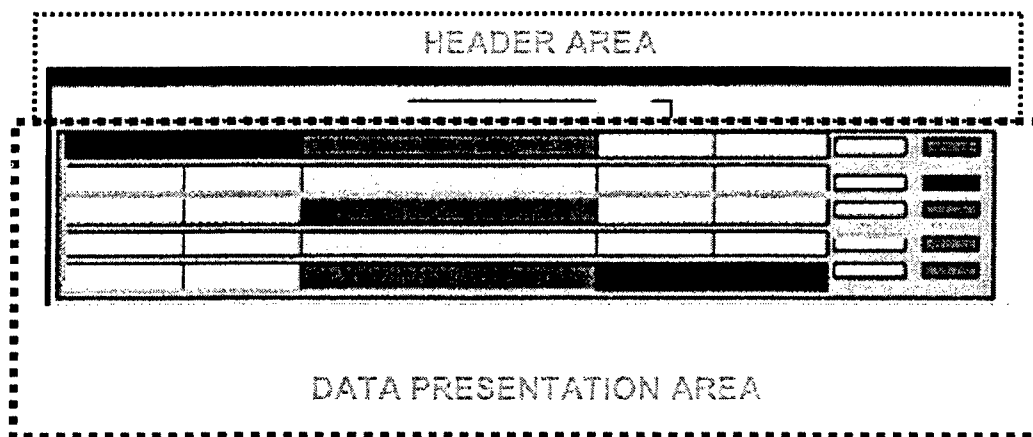


Figure D-1: Overview of Dip Summary Palette Layout

In the following sections we shall provide an overview of the interface features and information the DIP Summary Palette was designed to include.

Information Displayed in the Header Area

The Header area was intended to contain the following interface elements:

- Pull-down menus for general on-screen manipulation and configuration control in accordance with Windows protocols.

- A text window displaying the identification for the person responsible for requesting / processing DIP clearances on this particular mission.⁸⁵
- A checkbox to indicate whether or not the given mission involved Hazmat.⁸⁶
- Title headings for the Data Presentation Area elements arrayed below the Header Area.

These are the generic elements of information judged sufficiently important to include as default context for all instances of the DIP Summary Palette.

Information Displayed in the Data Presentation Area

The Data Presentation Area is the 'guts' of the DIP Summary Palette. This is the area of the WCSS widget in which key information is presented in a manner structured to fit the requirements of TACC decision making tasks as discerned in our KA and work-centered analyses. The Data Presentation Area is organized as a set of separate but closely interrelated subareas. This set is enumerated, and its members' organization illustrated, in Figure D-2.

⁸⁵ This feature was in accordance with our longstanding principle of cueing TACC users as to who is working a particular issue or subject.

⁸⁶ Inclusion of a Hazmat indicator was deemed advisable owing to the fact that Hazmat is the single parameter most commonly cited as affecting DIP viability. It has often been cited as a factor commonly overlooked or unrecognized by planning and execution staff when making time-critical decisions.

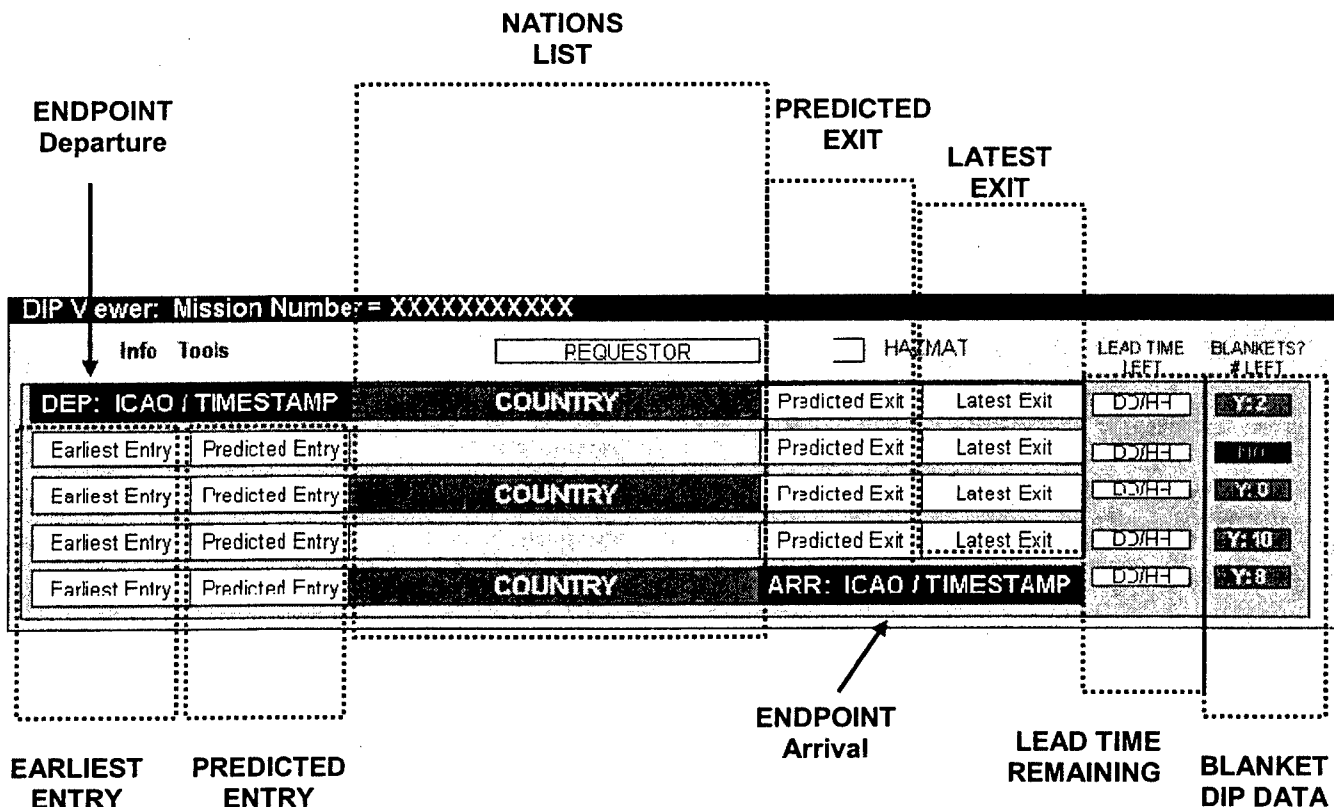


Figure D-2: Subsidiary Elements of the Data Presentation Area

The set of display subareas within the Data Presentation Area was designed to provide a structured set of interface elements and features as follows:

- The main component of the Data Presentation area is a central tabular array of information elements arranged so as to offer an orderly presentation of arrival and departure endpoints, nations traversed, and key time points relating to DIP's associated with the given mission.
- This tabular array constitutes a set of information elements organized in rows. These rows are ordered vertically (top-to-bottom) to reflect the temporal progress of the flight.
- Because DIP clearances are addressed nation-by-nation, each row represents the DIP data pertaining to one nation being traversed in the course of the mission.⁸⁷
- A specific information element specifying the Departure Endpoint for the mission's route is given in the upper left (earliest row in the flight sequence).

⁸⁷ It is presumed that there will be conventions for treating non-national spaces being traversed (e.g., international airspace over an ocean) in the same manner as nations. For the sake of this introduction, we shall refer solely to 'nations'.

- A specific information element specifying the Arrival Endpoint for the mission's route is given in the lower right (last row in the flight sequence).
- Each row is organized to reflect temporal sequence from left-to-right (left = earlier; right = later).
- In the center of each row is an element displaying the country being traversed. The set of these nation designations is termed the 'Nations List'.
- Each of the nation designations is color-coded to provide visual alerting on the status of DIP clearances for that particular nation.⁸⁸
- To the left (i.e., 'early side') of each row's central nation designation is a pair of data elements pertaining to entry times (into the nation). The outboard ('earlier') one displays the earliest feasible entry time, and the inboard ('later') one displays the predicted entry time.
- To the right (i.e., 'later side') of each row's central nation designation is a pair of data elements pertaining to exit times (from the nation). The inboard ('earlier') one displays the predicted exit time, and the outboard ('later') one displays the latest feasible exit time.⁸⁹
- The arrangement of the elements introduced so far provides an orderly protocol for reviewing a mission's DIP parameters in accordance with the sequence of the flight.
- Reading vertically across rows gives the sequence of flight across nations and from departure to arrival ports.
- Reading horizontally within a row gives the logical sequence of entry and exit parameters along with the associated nation and DIP alert status.
- Each of the nation designations is color-coded to provide visual alerting on the status of DIP clearances for that particular nation.
- Two columns to the right of each row provide additional data.
- These columns are visually segregated from the otherwise-integral row presentations in accordance with the fact they provide data relevant to the DIP processing, and not the DIP processed (i.e., the work and not the work results).

⁸⁸ Similar to other of our WCSS designs, this alert function employs a three-color 'stoplight' metaphor. A green color indicates the DIP status for the given nation is 'go' / 'completed'. A yellow color indicates that DIP clearance for the given nation is 'pending'. A red color indicates a 'no go' condition. This scheme provides for (e.g.) automated cueing on which of potentially several nations represent a DIP problem.

⁸⁹ The arrangement of these entry and exit time designations to either side of the central nation designation is quite deliberate. They are horizontally segregated by the nation designation to allow rapid discrimination between entry and exit data. They are horizontally ordered to allow coherent assessment of the four timepoints as they should be ordered in a feasible traversal of a nation. If the data displayed does not reflect this presumptive feasible ordering (e.g., if predicted entry is earlier than earliest feasible entry or predicted exit is later than latest feasible exit) the row should be flagged red to alert the user of a problem.

- The inboard column displays the conventionally-delineated lead time left for processing a DIP request for the country designated in the associated row.
- The outboard column displays two pieces of data relating to blanket clearances for the country designated in the associated row.
- The first piece of blanket clearance data is whether or not there are blanket clearances available for the given nation at all. This is cued on a 'yes / no' basis.

The second piece of blanket clearance data (only provided for nations offering blanket clearances - i.e., when the first datum is a 'yes') is the number of such blanket clearances remaining available at the present time.

Discussion

The DIP Summary Palette was designed to provide the same sort of one-stop 'viewer' capability the HISA Port Viewer represented. The layout of the rows and their subsidiary elements was intended to provide the most critical elements of DIP information in a structured fashion. During the FY03 work, it was noteworthy to learn that there is no structured summary of DIP data for a given mission. Such data is available, to be sure, but it must be laboriously extracted from (e.g.) the generally unstructured set of text documentation stored in the LogBook application. Although this relatively unstructured and text-intensive approach may suffice for the DIP planners who deal with it regularly, it is a cumbersome type of information support for other TACC team members who may need to check DIP information on a given mission. This cumbersome character is particularly detrimental for those who must quickly evaluate DIP status in support of time-critical decision processes (e.g., re-planning during the execution phase).

The organization of the row-wise data presentation in the DIP Summary Palette derives from the WCD principle that visualization should reflect the form of the subject matter as it is addressed in the course of the work process. In this case, the organizing principle is obvious. As documentary products being negotiated, DIP clearances are assigned and processed nation-by-nation. Relevant external points of contact, specific requirements, and procedures are similarly differentiable on the basis of national entities involved. Finally, the referential intersection of DIP clearances and flight progress is a sequence punctuated by the exit from one national space and entry into a subsequent one.

The DIP Summary Palette was designed to incorporate work-centered features analogous to those provided in our earlier WCSS concepts and prototypes. One such feature is summary alert presentation and coding to allow TACC team members to rapidly check the status of DIP clearances for a given nation. One striking feature of current TACC operations is the ironic combination of high mission criticality and low degree of team-wide situation awareness associated with DIP clearances.

The lead time and blanket clearance data elements were incorporated into the DIP Summary Palette concept to meet the WCD requirement that a given WCSS interface product should provide the user(s) with the full range of information necessary to not only evaluate the state of work being processed, but also the factors affecting the course of that work process. DIP application lead time is a factor which can 'make or break' the prospects for modifying a flight plan late in the planning phase or anytime during the execution phase. As a result, access to lead time requirements could facilitate evaluation of options for a variety of people outside the DIP shop. For example, providing TACC team members outside the DIP shop with a cue on the lead time requirements would enable them to identify 'no way' situations without wasting time on personal communication with a DIP specialist and facilitate their moving on to focus on feasible solution paths. Similarly, cueing non-DIP team members on blanket clearance availability would provide valuable clues as to whether there's a backup option when confronted with a priority requirement for generating or modifying DIP permissions on short notice.